THE
BIOLOGIC AND ECONOMIC ASSESSMENT
OF
REGISTERED FUMIGANTS

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PREFACE/PURPOSE

PLANNING PANEL

PREFACE

This report is a joint project of the U.S. Department of Agriculture, and State Land-Grant Universities, and was prepared by a team of scientists from these organizations in order to provide sound, current scientific information on the benefits of, and impacts of the loss of fumigants to agriculture.

The report is a scientific presentation to be used in connection with other data as a portion of the total body of knowledge in benefit/risk assessment in connection with regulatory activities under the Federal Insecticide, Fungicide, and Rodenticide Act.

Appreciation is extended to the Fumigant Planning Panel, Assessment Team Members and to all others who gave so generously of their time in the development of information and in the preparation of the report.

PLANNING PANEL

Purpose and Scope

This report has been prepared for the purpose of defining the impact of the loss of fumigants on selected commodities. Regulatory actions by the Environmental Protection Agency (EPA) over the past several years has resulted in registration cancellation for uses of a number of agriculturally important fumigant materials, including ethylene dibromide, carbon tetrachloride, carbon disulfide, ethylene dichloride and 1,2-dibromo-3-chloropropane. Other EPA actions such as the Data-Call-In Program, and the Label Improvement Program for Fumigants as well as the detection of 1,3-D in groundwater raises the specter of continuing attrition of fumigant materials.

While a comprehensive assessment, encompassing all registered fumigants and fumigated commodities would be desirable, resource constraints dictated that the assessment be limited to selected uses. Therefore, this report covers certain sites, pests and fumigants which were deemed representative and important to agriculture. It should not be inferred that fumigant uses not covered were considered to be less critical.

Biologic and economic assessment of the impact of the loss of fumigants is presented in six chapters and includes information on commodities impacted, associated pests, economic costs, alternatives, production losses, quarantine considerations and research needs. These six chapters focus on the following fumigant uses: stored corn, wheat, and peanuts; stored tobacco; post harvest quarantine uses on citrus, Hawaiian papayas, mangoes from the Carribean, deciduous fruits from Chile, cherries and Khapra beetle cargo; soil fumigant uses in citrus, cotton, forest nurseries, potatoes, tobacco, and tomatoes; bee equipment; and structural pest uses.

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SUMMARY

SUMMARY

The availablity of fumigants for the control of pests affecting agricultural commodities has significantly diminished over the last several years. Regulatory actions by the U.S. Environmental Protection Agency has resulted in the cancellation of all, or almost all of the uses of ethylene dibromide, carbon tetrachloride, carbon disulfide, ethylene dichloride, and 1,2,dibromo-3-chloropropane. The continued availability of the few remaining important fumigant materials is in question because of requirements of the Data-Call-In Program, the Label Improvement Program, and the detection of 1,3-dichloropropane in groundwater.

This report has been prepared by a team of State and Federal scientists to provide an assessment of the biologic and economic impacts of the loss of fumigants to American agriculture. Resource and time constraints limited the assessment to sites, pests and fumigants which were deemed representative and important. Commodities studied were stored wheat, corn and peanuts; stored tobacco; soil fumigant uses in citrus, cotton, forest nurseries, potatoes, tobacco and tomatoes; post harvest regulatory/quarantine uses on citrus, Hawaiian papayas, mangoes from the Caribbean, deciduous fruits from Chile, cherries and Khapra beetle cargo; bee equipment; and structural pest uses.

For each crop or comparable category, the assessment team estimated the quantities of the individual fumigants used and the pests controlled, the quantity and/or quality losses which would occur through potential withdrawal of fumigants, assuming that no alternative pest control method were employed, and the alternative quantity and/or quality losses incurred, if any, by withdrawing a fumigant or fumigants, but assuming that remaining fumigants and other pest

control alternatives were available. In addition, the economic costs and benefits were estimated based on differences in control costs and quantity and quality changes.

Stored Corn, Wheat and Peanuts

The fumigation of wheat, corn, and peanuts is a specialized form of remedial insect control in bulk stored commodities that presently involves only three approved fumigant compounds: aluminum phosphide, methyl bromide, and chloropicrin. No other type of pesticide treatment can reach infestation deep within the commodity bulk and no other chemical or nonchemical method of disinfestation offers the same combination of adaptability, simple application, low cost, and comparatively fast action as do fumigants.

Fumigant use in wheat and corn has evolved over the past 50 years from a market dominated up to the early 1960's by liquid fumigant mixtures of carbon tetrachloride, carbon disulfide, ethylene dichloride, and ethylene dibromide to the present time in which aluminum phosphide fumigants account for 85% of the fumigated grain, chloropicrin 9% and methyl bromide 6%. At their peak use, the annual liquid fumigant market was sufficient to treat 25% of the grain handled through the U.S. marketing system. Today, the combined market of aluminum phosphide, methyl bromide and chloropicrin treats only 15% of the approximate 10 billion bushels produced and handled annually.

Fumigant use in peanuts is characterized by reliance on aluminum phosphide materials for treating in-shell peanuts in warehouses and on methyl bromide for shelled peanuts in transportation containers. Liquid fumigant mixtures and chloropicrin have not been used to any extent on either in-shell or shelled peanuts.

State extension and pesticide regulatory officials consider fumigants as necessary pest management tools whose loss would adversely affect the quailty of grain in storage. Most believe that the loss of individual fumigants would increase the use of grain protectants and nonchemical control, but do not believe that non-fumigant control stategies alone would be sufficient to prevent insect infestations if all fumigant materials were discontinued.

The biological and economic consequences of insect infestations in grain are established by both government and grain industry regulations, guidelines, and marketing policies that interact to set the degree of market penalty applied for insect contamination and damages. The nature of the market penalty also influences the pest management strategy used to address the insect problem. Market discounting of grain for the presence of insects is a common practice especially at the initial point of delivery from farm storage to country elevator. Also, the level of insect activity present in grain being prepared for transhippment between other market points may cause the grain to be cleaned, reblended, or fumigated before it will pass insect requirements imposed by the buyer or insect tolerances permitted under official state or federal grain inspection guidelines. In the short term, fumigation remains the only practical solution to the immediate problem of reducing insect activity already present in

grain moving through the market system. In the long term, dependence on chemical fumigants could be reduced by a national reemphasis on the use of preventive measures (grain protectants, aeration cooling, prebin cleaning and treatment), particularly at the farm and country elevator levels. The shifting of primary pest management strategies to preventive rather than remedial procedures would reduce the overall frequency and severity of insect populations entering the grain market system, thereby limiting the situations in which chemical fumigations are necessary.

Recommendations are under consideration that will gradually lower insect tolerances and redefine the term "weevily" to more accurately reflect true levels of insect infestation when grain is graded. These changes will likely increase pressure throughout the marketing system to expand and improve control of insects in grain. Because pesticides continue to be the principal component of pest management practices in stored grain, their overall use will be increased.

The economic loss of removing all stored corn and wheat fumigants from the market, under current use patterns, would be about $18 million annually, of which $15 million would be due to quality losses. This loss is about 0.1 percent of the value of grain inventories. The economic loss of removing phosphine for wheat and corn would be about $15 million but would be much less for losing chloropicrin, $1.5 million, or methyl bromide, $700,000. The total loss of removing all stored peanut fumigants from the market would be about $28 million, primarily due to quality losses. This loss approximates 5 percent

of the value of January 1 peanut inventories. The economic loss from removing phosphine for stored peanuts would be $19 million and from methyl bromide about $600,000. While the aggregate losses for wheat and corn are not great, farmers with heavy insect infestations in their grain can suffer large financial losses without remedial treatments. Financial losses could increase if standards for insect infestations are tightened.

Stored Tobacco

The United States' tobacco industry needs a means to protect its inventory of $18 billion of stored tobacco. Unchecked insect infestations can result in downgrading or total destruction of the product. The two major pests of stored tobacco are the cigarette beetle (*Lasioderma serricorne* Fabricius (Coleoptera: Anobiidae)) and the tobacco moth (*Ephestia elutella* Hübner (Lepidoptera: Pyralidae)). Both of these insects are currently controlled by phosphine or methyl bromide. Virtually all tobacco in storage is fumigated once a year. Typically phosphine is used although methyl bromide is used in the cigar industry. Dichlorvos is also used as a space treatment throughout the year.

Insect damage manifests itself in the following manner: 1) loss of quantity and quality of leaf tobacco; 2) loss in value of manufactured tobacco; 3) loss of tax revenue; 4) loss of export tobacco sales; and 5) loss of consumer acceptance. It currently costs the industry an estimated $4.993 million to protect its crops using phosphine or methyl bromide and dichlorvos. There are a number of potentially useful alternatives but at this time most are neither economically or technologically feasible. Two possible exceptions are the use

of methoprene, a chemical pesticide that restricts insect development, and the use of cold storage. If the industry were no longer able to use phosphine, it is likely that methyl bromide, methoprene, and cold storage would be substituted for it. The increased cost of control would be approximately $2.5 million. In addition, several of these methods might have to be combined to provide adequate insect control. However, increased losses due to reduced quality and marketability would amount to $562.0 million. Should all chemical fumigants be lost the cost to the industry would be approximately $592.34 million.

The loss of all chemical fumigants would indeed prove costly to the tobacco industry. Yet, the loss of phosphine alone would prove to be nearly as serious a problem because the industry relies so heavily on its use. It should be kept in mind that the sudden loss of either phosphine or all chemical fumigants could prove to be very disruptive to this industry. Management would have to adjust production processes, alter product flow, possibly change marketing strategies, and make necessary changes in existing structural facilities. There is no easy way to estimate the cost that such sudden disorder might bring. Without chemical fumigants, management flexibility would be substantially reduced. If chemical fumigants were prohibited in the United States, and if the rest of the world were left with the use of chemical fumigants, the United States' tobacco industry would be at a substantial disadvantage. It is conceivable that firms might relocate abroad, shifting tobacco production and processing to countries with less stringent fumigation control and regulation. This could exacerbate an already unfavorable balance of trade. For the tobacco industry, there is no single panacea to chemical fumigants and at the present time the alternatives would prove expensive.

Regulatory/Quarantine

The movement of several agricultural and non-agricultural commodities is regulated by State, Federal, and foreign quarantines. Quarantine measures are legally mandated and include exclusion, inspection and chemical treatments. Two fumigants are used extensively to comply with domestic and foreign quarantine programs, ethylene dibromide and methyl bromide. Both materials have proven effective and insure that a variety of fresh fruits, vegetables, and other commodities are free from any undetected pest activity.

Ethylene dibromide has been used effectively for treating fresh products originating in areas infested by tropical fruit flies. The only presently authorized uses of this chemical as a post-harvest fumigant are on citrus and papayas to be exported from the United States, primarily to Japan. Methyl bromide has been used extensively to treat cherries for export, imported Chilean fruits, and khapra betle cargo.

There are no chemical alternatives to the fumigants presently used for quarantine purposes. Alternative nonchemical control technologies include the application of vapor heat, hot water dip, low temperature, and irradiation treatments. Areawide programs, such as established pest-free zones or pest eradication, are also considered as alternative control methods. Alternative controls have not effictively replaced the use of conventional fumigants in most cases. There is a need for increased research to develop effective and environmentally sound quarantine control measures. An effective alternative to the use of fumigants must be cost effective, commercially adopted by producers and consumers of regulated products, and accepted by quarantine officials.

Because of public health concerns, the use of fumigants is subject to pesticide regulatory actions. Fumigant residue levels on treated commodities cannot exceed safe limits imposed by EPA. Fumigant worker exposure levels must comply with OSHA regulations.

In the event of a complete ban on the use of fumigants for quarantine purposes, the aggregate economic impact to domestic producers of the selected commodities covered in this report varies according to the commodity, market destination, and adopted alternative control. Assuming that the quantity of the selected regulated commodities remains unchanged, the annual losses in producer net revenues are estimated in the range of \$3.2 to \$4.4 million in the longer term due to increases in control costs. Producers may realize gains only if effective pest-free zones or eradication programs on certain areas and crops eliminate the need for mandatory pest treatments under the same quantity assumptions.

Assuming that the quantity of the selected regulated commodities using alternative treatments decrease due to changes in fruit quality, the impact to producers will depend on whether changes in their gross revenues offset the increases in control costs. Under these conditions, the annual maximum loss estimated for domestic producers is between \$2.1 and \$2.4 million. Alternatively, producers may gain an aggregated \$8.3 to \$13.8 million. The wide disparity is indicative of the several combinations for alternative control adoption and the windfall effects of commodity price increases due to quantity decreases.

Domestic consumers will increase their expenditures for the selected regulated commodities in the range of \$4.5 to \$8.8 million if the quantity treated decreases.

Soil Fumigant Uses

Assessments were made of the impacts that the loss of one or more of four soil fumigants, 1,3-D, methyl bromide, chloropicrin, and metam, alone and in mixtures, may have in the control of plant-parasitic nematodes, diseases, weeds, and insects, that reduce yields and increase costs of production in the six crops that were evaluated. The crops include citrus (seedbed and field), cotton, forest nurseries, potatoes, tobacco (seedbed and field), and tomatoes (seedbed, and field production for fresh market and for processing).

Several chemical and nonchemical or cultural alternatives were considered for use, if these soil fumigants are to be cancelled. The chemical alternatives are three carbamates, aldicarb, carbofuran, and oxamyl, and three organophosphates, ethoprop, fenamiphos, and fensulfothion. The nonchemical alternatives include, but are not limited to, deep plowing, fallow, crop rotation, hand-weeding, and the use of resistant varieties. Impacts were measured by estimating differences in efficacy of alternatives, as expressed by yield decreases or increases, and by changes in related production costs. The impacts detailed in this assessment for these six crops indicate, by implication, the probable effects that the loss of soil fumigants may have on all other commercially-grown crops in the United States where fumigants are used to control soilborne pests.

In agricultural soils, in the field and in seedbeds, all plant-parasitic nematodes targeted for control, with only a few specific exceptions, are in the

soil mass. As a result, the primary site for application of nematode and root disease control measures is the soil mass. The number of pesticides registered for use that show practical levels of efficacy in that environment is small, and control is principally dependent on soil fumigants. Thus, the control of crop-damaging nematodes and soilborne diseases would be affected most severely by the loss of 1,3-D, methyl bromide, and chloropicrin, which are registered singly and in several mixtures, as preplant fumigants to fit agricultural soils for the production of a wide variety of crops.

The remaining soil fumigant, metam, also registered for a wide range of preplant uses, does not appear to be a candidate for cancellation because its principal degradation product, methyl isothiocyanate, which is also its active ingredient, is unstable and nonpolluting. It is, also, possibly adaptable to a number of postplant uses when it is applied using chemigation or nemagation technology. It is, however, relatively inconsistent in its activity, and usually is most effective in sites with irrigation capabilities. Because of this limitation, metam is not as versatile or as useful as the other soil fumigants despite its activity against nematodes, plant diseases, and weeds.

Disease control in crop plants is dependent on soil fumigants but less so than nematode control since not all diseases are soilborne or otherwise in the soil mass. However, 1,3-D and methyl bromide control various wilt, collar rot, and root-rot organisms that affect crop roots. These organisms should be suppressed if crop yields and production costs are to be maintained at levels that are practical for the grower. Metam can be used to control certain crop plant diseases but is subject to the limitations discussed above.

Negative impacts due to cancellation of one or more of the soil fumigants used to control nematodes and/or soilborne diseases will affect each of the crops in this study, and also, the numerous other crops grown in the United States, because the nonfumigant alternative pesticides that are available are less effective. Annual crops would show damages, expressed as reductions in yields and increased production costs, most rapidly; damages would escalate with time as the use of the less effective alternatives allow increasingly larger nematode and plant pathogen populations to persist in agricultural soils. Growers of certain crops, probably including potatoes and tomatoes, may be forced to abandon acreage that no longer supports economic crop production and move to other areas.

Perennial crops grow more slowly and may also show symptoms of damage from nematode and soilborne disease infections more slowly. With time, damages would escalate as these infections continue to increase.

It is extremely important that all perennial crops have the advantages of a proper "head start." This is usually accomplished by the use of measures designed to prevent or avoid infections. Citrus, evaluated in this study, may be considered as an example. Preventive measures in seedbeds are costly to apply and maintain but produce vigorous seedlings or rootstocks, free of nematode and soilborne diseases. Preventive measures can also be applied to tree sites in the field or can be applied overall to the field itself to help reduce populations of these damaging pests. These treatments help to support vigorous growth of the new plants in the field and make it possible for them to

come into early production. If preventive approaches are followed properly in the seedbed and in the field prior to planting, the damaging effects of nematodes and disease organisms can be zero in the seedbed and minimal in the field, in early stages of tree growth.

At the present time, effective preventive measures rely on soil fumigants. Their loss would create difficult production problems. In seedbeds, where eradication of these soil-inhabiting pests is practical, production would be forced to shift to the use of sterile soil (steam treated) or soilless mixtures as planting media in containers. The containers would have to be maintained on surfaces not in contact with the ground, and would require extra watering and protective shelters such as screen or slat houses. These changes would involve extra costs.

In the field, it would be necessary to adapt nonfumigant pesticides such as the carbamates and/or the organophosphates for use as preplant or postplant treatments in place of preplant fumigation with 1,3-D for overall treatments, and either 1,3-D or methyl bromide for tree sites. The nonfumigants are intrinsically less effective than the soil fumigants because they do not permeate the soil mass by diffusion as the latter can, and because current application technology is not capable of placing them in the soil as uniformly and as deeply as they need to be to exert maximum effect.

Soil fumigants that are effective for weed control are methyl bromide and metam, the former being considered the most effective. Metam's efficacy is limited in the field because of the relative difficulty of obtaining good distribution and activity in the soil.

The loss of these fumigants would have varied effects on weed control depending on the roles of these compounds in production practices. Control of weeds in citrus and in cotton would be unaffected. Loss of metam would have very little impact on potato production because adequate nonfumigant herbicides are available for production of this crop. Loss of methyl bromide would reduce weed control seriously in forest nurseries, tobacco seedbeds, and fresh market tomatoes. Although nonfumigant herbicides are presently used in conjunction with soil fumigation, they would not be adequate, if used alone, to control weeds in these crops.

As a result, a large increase in handweeding would be the only practical alternative to enable the maintenance of yields in these three crops at current levels. Extensive handweeding probably would be impractical and labor could be difficult to obtain for this purpose in the United States. The result would be serious impairment of the production of these crops.

The crops evaluated in this assessment, for the most part, do not have serious soil insect problems. Therefore, soil fumigants are not specifically recommended for their control since the availability of nonvolatile insecticides appears to be sufficient for control purposes. Soil fumigants are primarily

used for the control of nematodes, soilborne diseases and, to a limited extent, weeds, while soil insect control is only an indirect benefit.

However, this indirect effect of soil fumigants on soil insects is not fully realized because, to date, there is little or no information on the range of organisms that they control. For example, in Florida, tomatoes may suffer increased damage from mole crickets, rootworm larvae, flea beetle larvae, white fringed beetle larvae, and even termites, if soil fumigants are not used. In North Carolina, damages to tomatoes from wireworm larvae may increase. If soil fumigants cannot be used in tobacco seedbeds, increased damage may occur from wireworms, cutworms, midge larvae, mole crickets, and white fringed beetle larvae.

Fortunately, available nonvolatile insecticides could control potential insect problems which may arise. Therefore, on a national level, the loss of soil fumigants, in the short range, should not have a significant impact on the control of soil insects. The long range impact that the the loss of soil fumigants and the possible increased use of nonfumigant carbamates and/or organophosphates for control of nematodes, soilborne diseases, and weeds, may ultimately have on the control of soil insects that damage crops is speculative.

Estimated losses in each of the crops in this assessment due to combined effects of nematodes, plant diseases, and weeds indicate heavy reliance on soil fumigants. It also anticipates potential increases in production costs and

decreases in yields if soil fumigants become unavailable, forcing the use of less efficient control alternatives.

Citrus would suffer significantly. The use of sterile mixes, aldicarb and/or fenamiphos in 26 percent of seedbeds would increase production costs by an estimated $500 per acre. In the field, citrus yields would decrease by an estimated 25 to 30 percent, and such decreases could, with time, possibly escalate to 50 percent in 0.4 percent of the acreage.

Cotton production, in the face of the loss of soil fumigants, would suffer an estimated 3 percent loss in 0.4 percent of its acreage.

Forest nurseries require disease and weed control in 50 percent of planted acreage. As a result of the loss of soil fumigants, there would be no means of controlling diseases and weed control would be dependent on handweeding. As a result, forest nurseries would sustain an estimated 50 percent decrease in yield and an estimated increase in production costs of $350 to $450 an acre.

The nineteen percent of potato acreage that requires nematode, disease, and weed control would be dependent on less efficient alternatives for the lost soil fumigants such as carbamates and/or ethoprop, an organophosphate, for nematode control, with no alternatives available for other needs. The use of these nonfumigant compounds would be associated with yield decreases ranging from 15 to 38 percent, with losses escalating as nematode populations continue to escalate.

The loss of soil fumigants promises to have extremely serious effects on tobacco and tomato production. In tobacco, seedbeds would be entirely dependent on organophosphates and cultural practices for nematode control, sterile mixes for control of diseases, and hand labor to suppress weeds. It is anticipated that the use of sterile mixes would entail an estimated $200 per acre increase in production costs. Fifty percent of field tobacco acreage requiring nematode and disease control would also have to rely on the organophosphates and on metalaxyl, with an estimated 4 percent decrease in yield and $110 per acre increases in production costs.

There would be similar problems in 46 percent of tomato seedbeds. Nematode control with ethoprop and sterile mixes would increase production costs by $200 an acre, similar to those projected for other seedbeds in this assessment. Field production in 52 percent of acreage devoted to fresh market would require nematode, disease, and weed control, and 31 percent of acreage used for processing tomatoes would need nematode and weed control. However, weed control by means of napropamide and hand labor would be the only control measures available. Estimated losses, due to the lack of soil fumigants would range from 10 to 66 percent in fresh market tomato production, and from 10 to 19 percent in processing tomatoes.

It should also be noted that growers do not necessarily withstand just a straight percent loss in net return. At some point an individual operation may become unprofitable and thus be closed down. This results in total loss of that producing unit. Hence, there may be a greater impact on total production of the crop than is implied by the estimated percent of yield loss and a total impact on those growers who must close down their operations.

In addition to the crops evaluated in this assessment, there are many other crops, most notably strawberries and wintergrown vegetables, which depend upon fumigation for weed control. There are very few herbicides registered for controlling weeds in these crops and the loss of soil fumigants would result in drastic restrictions in our ability to produce these crops economically in the United States.

The greatest economic impacts of fumigant regulation would occur if all fumigants were lost, so that no fumigant could serve as an alternative for any other. Assuming that all soil fumigants were lost, the economic impacts are estimated to be as follows for consumers and producers:

Impacts on consumers would occur through short-term increases in retail prices. The annual average price of the six products studied would rise as follows: fresh tomatoes, by 53 percent; potatoes, by 11 percent; canned tomatoes, by 8 percent; and cigarettes, by 4 percent. The loss of fumigants would have no effect on prices of cotton products, citrus fruit, or frozen juice.

Impacts on producers are complex, because changes in both farm costs of pest control and market prices of farm products may affect a producer's economic position. When the loss of fumigants causes crop yield to fall and total crop output to decline, crop prices will tend to rise, and total revenue received by producers will tend to increase. Conversely, an increase in production tends to bring lower total revenue. Because increases in farm costs (after fumigant loss) of controlling soil-borne pests tend to be substantially less than increases in total revenue received by farmers, on the average farmers growing a crop tend to be better off as a group when there is a yield loss and less total production. However, farmers who formerly used fumigants could be hurt severely by fumigant cancellation.

If all fumigants were lost, producers who formerly fumigated would be affected more than producers who did not fumigate, assuming that the loss of fumigants did lead to a change in crop yield. Those who fumigated would experience the

effects of changed output from their acreage, assuming that planted acreage remains the same both before and after fumigant loss. The effects would include a changed market price for the crop, as well as a changes in pest control cost as farmers adopted alternatives to fumigation for the control of soil-borne pests. By contrast, those producers who did not fumigate would experience the effects of a changed market price, but no yield change nor cost change. As a result, loss of fumigants may, in effect, cause a transfer of income between producers who fumigated and those who did not. Fumigant loss impacts on economic averages or other aggregates for <u>all</u> planted acreage should be interpreted with caution because important differences between economic impact on formerly treated vs. untreated acreage may be concealed by the aggregation.

If all fumigants were lost, the average impacts on producers of the several crops can be summarized as follows: Cotton farmers would not be affected, since very little cotton acreage is treated with fumigants, and minimal yield loss occurs when fumigants are withdrawn. For citrus growers, the impact of fumigant loss would be slight; in dollars the increase in revenue to all growers would be only 1 percent of crop value. However, on that acreage where fumigants can no longer be used to treat for nematodes and diseases around mature citrus trees, yields are projected to decline 25-30 percent in the short run. Over the long run, the decline could be greater. In addition, the loss of fumigants used in about one-fourth of citrus nursery seedbeds could lead to an increase in production costs of about $500 per acre on treated acreage. Of the crops studied in this report, only citrus is a perennial

(tree) crop. Because of that, the long-run impact on the citrus industry in the absence of fumigants could be considerably greater than the minor impact shown by the short-run analysis.

The impact of fumigant loss on tobacco producers would be felt in two stages. First, there would be an increase in production cost of about $200 per seedbed acre at the tobacco seedling stage of production, as sterile mixes, nonfumigant chemicals, and handweeding were used to substitute for fumigant control in seedbeds. Second, at the field stage of production there would be an additional $98 increase in control cost per field acre because of lack of field fumigation. Overall, yield loss on treated acres would be about 4 percent. Considering only the combination of smaller crop, higher market price, and greater control costs, the net impact on tobacco producers would be almost negligible. However, allowing for the fact that farmer returns are tied to the Federal tobacco support program, the impact of fumigant loss would be to subtract the amount of control cost increase from market and program returns to those growers who used fumigants. It is estimated that 100 percent of the tobacco seedbed acreage and 50 percent of the tobacco field acreage is fumigated.

The loss of all fumigants would severely affect growers of forest tree seedlings in both the South and the North. In the South, grower net returns are projected to decline by 39 percent as seedling yields fall by 75 percent on treated acreage. Over 95 percent of tree seedbed acreage is fumigated in the South each year, where seedlings are harvested after one year's growth. In the North, where seedlings can be harvested only after 2 or 3 years' growth, almost all seedbed acreage is fumigated, as in the South, but only

about 23 percent of the acreage is treated in any given year. Thus, the first year after fumigant loss northern tree seedling growers as a group would be better off by about 6 percent of crop value because seedling prices would rise. However, in subsequent years both northern and southern growers would have to incur higher costs of seedbed treatment without fumigants.

In the absence of all fumigants, potato growers in the West (as a group) would experience a 20 percent increase in net revenue, while potato growers in the East (as a group) would show a net revenue increase of 8 percent. On treated acreage, yields would be lower by 20 percent in the West and 34 percent in the East. The decrease in total production would lead to higher prices, resulting in higher revenue. Because the demand for potatoes, like other products in this study, is relatively stable, changes in the quantity supplied can lead to large price swings. The percentage rise in price of western potatoes, however, is greater than the rise in price of eastern potatoes because western supply drops more, since a much greater share of acreage is treated with fumigants in the West. Thus, growers as a group in both the East and West benefit as prices rise and control costs go down, but those in the West benefit more. However, a longer run concern is that the lower control costs are the result of eliminating control of soil-borne potato diseases, an important factor for possible long-term analysis.

Fresh tomato growers (as a group) benefit slightly from increased net revenues of 3 to 4 percent (West and East) as all fumigants are withdrawn. However, these small and similar numbers mask two different situations in the East and West, each of which involves some rather large changes. On treated acreage,

eastern tomato yields decline by 60 percent, leading to sharply lower total production and much higher prices; yet, the greater revenue from these higher prices is almost cancelled out by much higher control costs, since about 63 percent of fresh tomato acreage in the East is fumigated. Among eastern growers, the 4 percent overall revenue increase conceals some very large distributional impacts among growers, especially between those who treat with fumigants and those who do not. In the West, by contrast, only 9 percent of acreage is treated, although on that acreage, yield loss with no fumigation runs to 25 percent and costs of alternative control are considerably higher than with fumigation. As higher prices and control costs are balanced, western growers would come out slightly ahead.

Returns to processing tomato growers in the West would rise by 7 percent of crop value if fumigants were not available, mainly because prices would rise as yields dropped by about 11 percent on treated acreage, and total production declined. Control costs, especially for weeding, would rise too, but not enough to negate the benefits of the price increase. However, the increase in control costs would be borne most severely on those acres--about one-third--actually treated with fumigants and whose control practices were thus affected by fumigant withdrawal.

As a group, growers of citrus seedlings in the West would experience a decline in net revenues of about 5 percent of seedling crop value. Growers' total "net" would fall because, without fumigants, costs of controlling soil pests would rise by more than $500 per acre.

In the East, where almost half of the tomato seedling industry treats with fumigants, as measured by treated acreage, growers as a group would find revenues higher by 11 percent following loss of all fumigants. Yield loss would be severe--a 40 percent yield decrease for those growers whose control practices were affected. For these growers, the higher prices they would receive for seedling transplants would not compensate for higher costs of pest control.

Results involving regulatory actions less drastic than the cancellation or withdrawal of all fumigants are of lesser magnitude than the results above, which are based on hypothetical loss of all fumigants. Results for less drastic regulation range downward from the above impacts to no impact at all for action involving the loss of chloropicrin only.

Apiculture

Four fumigants have been or are currently being used in Apiculture. These include ethylene oxide (EtO), which is used to control bee diseases; ethylene dibromide (EDB), paradichlorobenzene (PDB) and aluminum phosphide (ALP) which are used to control the greater wax moth (GWM).

Annual EtO usage for control of bee diseases is estimated at 1,500 pounds and the equipment thereby salvaged would cost beekeepers in excess of $862,000

to replace. Fumigation with EtO is conducted under authority of EPA 24c labeling; consequently each state maintains rigid controls on its use. There are no satisfactory alternatives to EtO for fumigating bee hive equipment for disease control.

It is no longer legal to sell or use EDB for controlling GWM. Until recently, most of the 1,600 commercial beekeepers (over 300 colonies) in the U.S. used EDB (85% a.i.) to fumigate empty honeycombs. A few years ago, an estimated 20,000 lbs of EDB was being used by sideline and commercial beekeepers annually. Over the last few years EDB use has decreased; last year (1985) no EDB was sold by any bee supply house for GWM control.

When current supplies of EDB are expended, PDB will become the predominant fumigant for controlling GWM, increasing beekeepers costs and losses by about $270,000 annually. If PDB is cancelled, users will switch to BT and ALP, decreasing costs and losses by $14,687. This decrease in cost does not take into account the extra costs to commercial beekeepers to secure pesticide applicator licenses and to upgrade storage buildings to make ALP fumigation feasible and legal.

If PDB and ALP registrations are cancelled, no fumigants remain. Only BT, a microbial insecticide, would be available. Under these conditions, costs and losses are expected to increase by $27.5 million over costs and losses using currently registered materials.

Structures

Fumigation is an economical and effective method of controlling structural insect infestations. It is commonly used to control drywood termites in the southeast, along the Gulf coast and the southwest, including Southern California. Fumigation for Formosan termites is common in Hawaii and is becoming more common in the mainland United States. Structural fumigation for beetles commonly takes place along the east coast, including the southeast region of the United States. The fumigants used are sulfuryl fluoride and methyl bromide.

Costs based on average figures for chemical cost ($300 to $500/structure) and industry figures for performing fumigation ($300/structure) would indicate an annual total of approximately $24.5 million for fumigating 35,000 structures. If fumigants were not available, and repairs, replacement, and localized treatment methods were used as alternatives, an estimated average figure would be approximately $2,500/structure. This would result in a figure of $87.5 million for alternative treatment, a difference of $63 million. There is also a potential for major structural damage in some instances, which would result in additional repair costs between $10,000 to $15,000/structure for repair work.

It is also important to note that loss of fumigants to treat infested houses could result in loss of loan approval by the Federal Housing Administration, Farmers Home Administration, and the Veterans Administration.

STORED
CORN, WHEAT, PEANUTS

BIOLOGIC AND ECONOMIC
ASSESSMENT OF STORED
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BIOLOGIC AND ECONOMIC ASSESSMENT OF STORED CORN, WHEAT AND PEANUT FUMIGANTS

INTRODUCTION

Over the past 25 years the amount of grain handled annually through the U.S. grain marketing system has more than doubled from 5 billion bushels to more than 10 billion bushels. Producer storage programs authorized by the Food and Agriculture Act of 1977 (Public Law 95-113, 91 STAT. 913 et Seq.) permitted producers to store their grain during periods of abundant supply, thus allowing them to retain control of their crops until it was to their economic advantage to release them into the market system. As a result, on-farm bin construction increased at a rate of approximately 600,000 bu./year to provide a total farm storage capacity of nearly 12 billion bushels by 1985.

The national growth in both grain volume and storage capacity is an interrelated product of government policy, high production, and the vagaries of international grain marketing. Large foreign grain sales that significantly reduced grain reserves in the early 1970's dramatized the fact that the U.S. was becoming committed to the business of producing grain specifically for international sale. World inflation and improved production in some countries previously buying grain severely softened the world grain market and U.S. producers faced with depressed grain prices have turned increasingly to storage of grain on the farm in anticipation of improved markets in the future. Futhermore, large stocks of grain held under CCC warehouse contracts will likely have to remain in storage and future shortfalls in storage space will result in increased use of emergency and temporary storage structures.

The biological consequences of this expanded grain volume and extended storage tenure will be increased infestation and serious losses from insect attack unless effective and timely pest management procedures are employed. For more than 50 years chemical grain fumigants have provided the principal remedial procedure used to control developed insect infestations in bulk stored grain. This report examines the past and present use of the three fumigant compounds (aluminum phosphide, methyl bromide, and chloropicrin) currently approved by EPA for use in wheat, corn, and peanuts (aluminum phosphide and methyl bromide only); the regulatory, economic, and marketing factors that will effect their future use; and, the economic and biological impact of their possible cancellation.

FUMIGATION (GENERAL)

Grain

Fumigation has been the principal remedial procedure used for controlling developed insect infestations in grain and milled products for more than 50 years. Fumigants are chemical pesticides that are distributed through the grain as gases to kill destructive insects attacking the grain. Fumigants may be applied directly to the grain as gases (example: methyl bromide) that form when pressurized liquids are released into the atmosphere, as liquids (example: chloropicrin) that vaporize when exposed to the air, or as solids (example: aluminum phosphide) that produce gases on exposure to moisture in the air. The combination of high volatility, diffusion capability, and high toxicity are properties that make fumigants uniquely suited for short-term treatment of enclosed spaces. Grain fumigations, however, are effective only when the storage structure is sufficiently tight to hold gas concentrations in the grain long enough to be lethal to storage pests (about 1 to 5 days depending on chemical used and grain temperatures). Fumigants exert their effect on grain pests only during the time in which the gas is present in the insects' environment. After the fumigant diffuses out of the grain, no residual protection is left behind that is lethal to insects and the grain is again susceptible to reinfestation. Fumigation becomes an essential control measure when no other pesticide treatment or other control means can reach the infestation deep within the grain mass and when marketing practices limit the time available to achieve effective control.

Peanuts

The use of fumigants for the control of insects in farmers stock (inshell) peanuts has been very limited, due primarily to the construction of the warehouses in which the peanuts are stored. Most of these warehouses are of a type construction that makes them difficult or impossible to adequately seal for fumigation. The use of fumigants in peanuts has traditionally been limited to fumigation of shelled peanuts in the boxcars or trucks used for transportation to processors. With the development of phosphine with its slow release properties and excellent penetrating properties, some use has been possible in farmers stock storage.

History of Fumigant Use in the U.S.

During the 30 year span between the 1930's and the early 1960's, liquid fumigant mixtures composed primarily of carbon tetrachloride, carbon disulfide, ethylene dichloride, and ethylene dibromide dominated the U.S. fumigant market. At their peak in the late 1950's and early 1960's, about 5 million gallons of the mixtures were used annually. This is enough material to treat 25% of the approximately 5 billion bushels of grain handled through the U.S. marketing system during that period. Following the introduction of phosphine-producing fumigants, the use of liquids declined steadily to a volume of less than 2 million gallons annually by the early 1980's. The significance of the decline in liquid fumigant use becomes even more apparent when viewed against the fact that the amount of grain handled annually through the marketing system has nearly doubled to 10 billion bushels in recent years. When manufacturers of liquid fumigants voluntarily withdrew registration of these chemicals in 1984, only about 5% of the grain moving through the market system was being treated with liquid fumigant mixtures.

The use of methyl bromide in bulk grain reached its peak in the late 1950's when provisions of Public Law 518 (effective July 22, 1955), the Miller Amendment, limited the amount of pesticide residue permitted on food crops. The initial legal residue tolerance established for methyl bromide was 50 ppm inorganic bromide for most grain. Thereafter, most of the methyl bromide market in off-farm bulk grain storage was replaced with phosphine-producing formulations. Methyl bromide is now rarely used for the treatment of farm stored grain, except by commercial applicators.

Re-establishment of methyl bromide as a dominant fumigant in the treatment of bulk-stored grain would require modification of existing aeration systems to permit recirculation of the gas and a reappraisal of the residue tolerances that restrict the use of methyl bromide. Such actions are now in progress by the Methyl Bromide Industry Panel, Lafayette, Indiana, which has petitioned EPA (Federal Register, Vol. 51, No. 53, March 19, 1986) for establishment of (organic) bromide residue tolerances for a variety of commodities including cereal grains.

Chloropicrin, an effective material, but difficult to use because of its irritating properties, has never been a dominating factor in grain treatments. Originally marketed in glass bottles and applied as a liquid fumigant, it was eventually formulated with methyl bromide or pressurized with methyl chloride in metal cylinders to facilitate its use in large bulk grain storages constructed during the 1950's. Cylinders of chloropicrin that could be pressurized with air or nitrogen just before application were also developed. The development of the pressurized cylinders enabled fumigators to apply chloropicrin directly and remotely to bulk grain by the recirculation method (27). During the early 1960's, this method of chloropicrin treatment was used extensively in flat storages by Cooperative elevators throughout the mid-prairie states.

Aluminum phosphide formulations were first introduced in the U.S. in 1958 and for more than a decade its market was virtually controlled by a single company. Guidelines for marketing the material were established by the company and their policy of selling the material to "trained" applicators only was a significant departure from marketing methods used for other fumigant materials. By the end of the 1960's, phosphine-producing fumigants had captured the major share of the U.S. fumigant market for commercial grain storages. The reasons for the growth in the use of phosphine-producing fumigants at the expense of other fumigant materials are varied and encompassed such factors as reduced fumigant storage and handling (tubes and flasks of pellets and tablets versus cylinder, barrels or cans of other fumigant materials); less expensive application equipment (hollow probes versus pumps, storage tanks, and pressurizing equipment); automated application (tablet and pellet dispensers attached to grain belts); and a perceived safety edge for solid materials in their delayed release of gas following application to grain.

Today, market strategies for phosphine-producing fumigants are still directed primarily at the commercial elevator market, with little overall effort aimed specifically at the private applicator on-farm market. The major distributors of phosphine fumigants have expressed concern about potential misuse of these materials, especially by farmers who have not received adequate training in their proper use.

Realistically, their concerns are further motivated by a general feeling that "control" over the product's use will be lost with expanded farm use and as a result their liability in case of accident could be materially increased.

Methyl bromide, aluminum phosphide formulations and chloropicrin are classified as restricted use pesticides. Individuals who use or supervise the use of "restricted use" pesticides are required to demonstrate that they possess a practical knowledge of pest problems and pest control practices, and such knowledge must be verified by a responsible State agency through the administration of an approved applicators certification system. Unfortunately, training on the specific use of grain fumigants is often not provided to farmers during private applicators certification programs in which emphasis is placed primarily on field pesticide applications.

MARKETING PARAMETERS FOR WHEAT, CORN AND PEANUTS

The production, storage, and utilization of the commodities addressed in this assessment provide the physical marketing parameters against which the use of grain fumigants and the possible impact of their loss are measured.

Production

Wheat: There are five major classes of wheat grown in the United States (12). The most important of these is hard red winter wheat which accounts for half of the total production and is grown primarily in the states of Kansas, Nebraska, Oklahoma, and Texas. Hard red spring and durum wheat are produced in Minnesota, Montana, North Dakota, and South Dakota. The Pacific Northwest (Idaho, Oregon, and Washington) produces most of the U.S. supply of soft white wheat and Illinois, Indiana, Ohio and Missouri produce the fifth class of wheat--soft red winter wheat. Susceptibility to insect attack during storage is not significantly different between wheat classes and no individual variety commonly produced in the U.S. has been found to be especially resistant to postharvest insect damage.

Corn: Corn is harvested in 41 states: however, more than 80% of the commercial production is centered in the Corn Belt which extends from Eastern Ohio to the Western sections of Iowa and Missouri (15). The most important producing states are Illinois and Iowa, which generally grow about 40% of the total production. Most of the field corn harvested for grain is dent corn.

Like wheat, the development of corn varieties resistant to stored-grain insects has not been achieved, however, research in progress to develop corn hybrids more resistant to stress cracking and subsequent breakage could provide for a less favorable environment for the development of certain insect species.

Peanuts: Peanuts are grown in three primary production areas of the United States. These are the Virginia-Carolina area (Virginia and North Carolina), Southeastern production area (Georgia, Florida, Alabama, and South Carolina) and the Texas-Oklahoma area. Lesser amounts are also produced in Mississippi, Arkansas, and New Mexico. The climate in these production areas is suitable for insect development throughout most of the year and infestations often build up to high levels before the peanuts are processed. This led to the widespread use of chemical protectants on farmers stock peanuts and cold storage of shelled peanuts.

Supply and Storage Positions

In recent years about 65% of the corn production and 80% of the wheat production has been in storage during the market year in either on-farm or off-farm locations. U.S. total corn and wheat stocks by position for each quarter are in Table 1. During most of the calendar year about two-thirds of the corn in storage is located on the farm. Wheat stocks are more evenly divided with only about 15% less wheat held in on-farm bins than in off-farm locations. Storage locations across the country for wheat are summarized in Table 2 and show nearly three-fourths of the on-farm wheat storage located in the Northern Plains and mountain states with more than half of the off-farm wheat storage concentrated in the Plains area. Corn stocks (Table 3) in both on-and-off farm locations are found primarily in the Corn Belt region, but also occur in significant volumes in the Lake States and Northern Plains.

Most peanuts are delivered as farmers stock (in shell) peanuts to commercial warehouses at harvest (Table 4) and are not stored directly on the farm. The peanuts are held in the commercial warehouse until they are shelled,

after which they are shipped to manufacturers of peanut products or placed in cold storage to prevent insect damage and preserve quality during extended storage periods.

Types of Storage Facilities

Grain is stored on the farm in several types of structures varying from cribbed or wire mesh enclosures for storage of ear corn to elaborate bin layouts equipped with grain dumps, vertical elevators and conveyors to transfer grain (10).

The most common type of storage on the farm is flat bottom round metal bins with capacities of 1,000 to 40,000 bushels. Most modern farm bins are equipped with some type of aeration equipment ranging from a simple perforated duct placed on the floor of the bin to a more elaborate system consisting of an entirely perforated floor that forms a plenum chamber beneath it. The total capacity of on-farm storage increased steadily during the past decade until it slowed dramatically by the PIK program and the loss of low-cost government loans for new bin construction. Nevertheless, over the past 15 years the farm storage capacity has increased from 4.6 billion bushels in 1970 to nearly 12 billion bushels in 1985.

Off-farm storages are principally commercial elevators or warehouses licensed by State or Federal authorities for the storage and marketing of grain. This system is comprised of over 15,000 country elevators, terminal elevators, and elevators located at processing plants with an estimated storage capacity of 8.1 billion bushels (24). Country elevators receive grain directly from producers, reload it into trucks and railcars and transport it to other points in the marketing system. Large country elevators approach the size of some terminal elevators and have handling systems capable of receiving and transferring grain at rates of 10,000 to 30,000 bushels/hour. Port terminal elevators and elevators located at processing plants are, in effect, the end-of-the-line and represent the last stop of grain in the marketing channel before being processed or exported. Although a grain elevator cannot be precisely characterized on the basis of storage capacity alone, most terminals

TABLE I. CORN AND WHEAT STOCKS BY POSITIONS, U.S. TOTAL
January 1, April 1, June 1, October 1
For Years 1982-1984 and 3-Year Average
1,000 Bushels

CROP	REPORT DATE	1982 ON-FARM	1982 OFF-FARM	1982 TOTAL
Corn	January 1	5033830	1933826	6967656
	April 1	3625935	1505898	5131833
	June 1	2758514	1145571	3904085
	October 1	1252491	929926	2182417
	Avg. Jan.-Oct.	3167693	1378805	4546498

REPORT DATE	1983 ON-FARM	1983 OFF-FARM	1983 TOTAL
January 1	6016947	2267297	8284244
April 1	4292402	1954869	6247273
June 1	3133259	1829055	4962314
October 1	1531677	1608634	3140311
Avg. Jan.-Oct.	3743571	1914964	5658536

REPORT DATE	1984 ON-FARM	1984 OFF-FARM	1984 TOTAL
January 1	3079963	1832904	4912867
April 1	1933652	1317558	3251210
June 1	1213068	932007	2145075
October 1	347853	375370	723223
Avg. Jan.-Oct.	1643634	1114460	2758094

3--YEAR AVERAGE 1982-1984

REPORT DATE	ON-FARM	OFF-FARM	TOTAL
January 1	4710247	2011342	6721589
April 1	3283996	1592775	4876772
June 1	2368280	1302211	3670491
October 1	1044007	971310	2015317
Avg. Jan.-Oct.	2851633	1469410	4321042

TABLE 1.--Continued

CROP	REPORT DATE	1982 ON-FARM	1982 OFF-FARM	1982 TOTAL
Wheat	January 1	955579	1222428	2178007
	April 1	748408	808704	1557112
	June 1	581007	5829021	1163909
	October 1	1421231	1566044	2987275
	Avg. Jan.-Oct.	926556	1045020	1971576
	REPORT DATE	1983 ON-FARM	1983 OFF-FARM	1983 TOTAL
	January 1	1166244	1354465	2520709
	April 1	886402	990688	1877090
	June 1	694894	845846	1540740
	October 1	1248833	1717268	2966101
	Avg. Jan.-Oct.	999093	1227067	2226160
	REPORT DATE	1984 ON-FARM	1984 OFF-FARM	1984 TOTAL
	January 1	1015409	1310964	2426373
	April 1	7712122	9869248	1758136
	June 1	591650	806996	1398646
	October 1	1217308	1522679	2739987
	Avg. Jan.-Oct.	898895	1156891	2055786
	3--YEAR AVERAGE 1982-1984			
	REPORT DATE	ON-FARM	OFF-FARM	TOTAL
	January 1	1045744	1295952	2341696
	April 1	802007	928772	1730779
	June 1	622517	745248	1367765
	October 1	1295791	1601997	2897788
	Avg. Jan.-Oct.	941515	1142992	2084507

January 1984 and January 1985 Crop Productions Reports

TABLE 2. SHARE OF ALL WHEAT STOCKS BY REGION
October 1 Reporting Date for 1982, 1983, 1984
By Individual Year and 3-year Average

REGION	1982 ON-FARM	1982 OFF-FARM	1982 TOTAL
Northeast	0.30	1.74	1.04
Lake	10.00	5.32	7.55
Corn Belt	2.39	8.88	5.78
No. Plains	51.72	36.76	43.88
Appalachia	1.12	2.06	1.61
Southeast	0.67	0.63	0.65
Delta	0.54	2.41	1.52
So. Plains	3.49	22.05	13.22
Mountain	23.89	8.16	15.59
Pacific	5.89	11.77	8.97
Unallocated	0.00	0.21	0.19
USA TOTAL	100.00	100.00	100.00

	1983 ON-FARM	1983 OFF-FARM	1983 TOTAL
Northeast	0.48	1.26	0.93
Lake	9.53	4.87	6.82
Corn Belt	3.69	10.03	7.37
No. Plains	36.09	40.14	51.66
Appalachia	1.87	1.61	1.11
Southeast	0.54	0.64	0.60
Delta	0.37	2.19	1.43
So. Plains	4.35	21.52	14.34
Mountain	26.33	8.79	16.09
Pacific	7.68	12.63	10.56
Unallocated	0.00	0.12	0.12
USA TOTAL	100.00	100.00	100.00

TABLE 2.--Continued

REGION	1984 ON-FARM	1984 OFF-FARM	1984 TOTAL
Northeast	0.46	1.45	0.99
Lake	10.02	7.40	8.56
Corn Belt	2.83	8.82	6.15
No. Plains	51.66	34.33	42.03
Appalachia	1.11	1.96	1.58
Southeast	0.67	0.41	0.53
Delta	0.38	2.19	1.39
So. Plains	4.03	20.61	13.24
Mountain	21.74	8.85	14.52
Pacific	7.11	13.60	10.72
Unallocated	0.00	0.38	0.29
USA TOTAL	100.00	100.00	100.00

	3-YEAR AVERAGE 1982-1984		
	ON-FARM	OFF-FARM	TOTAL
Northeast	0.41	1.48	0.99
Lake	9.85	5.86	7.64
Corn Belt	2.97	9.25	6.44
No. Plains	49.72	35.73	42.02
Appalachia	1.16	1.96	1.60
Southeast	0.62	0.56	0.59
Delta	0.43	2.26	1.44
So. Plains	3.96	21.39	13.60
Mountain	23.99	8.60	15.40
Pacific	6.89	12.67	10.08
Unallocated	0.00	0.24	0.20
USA TOTAL	100.00	100.00	100.00

TABLE 3. SHARE OF ALL WHEAT STOCKS BY REGION
January 1 Reporting Date for 1983, 1984, 1985
By Individual Year and 3-year Average

REGION/STATE	1983 ON-FARM	1983 OFF-FARM	1983 TOTAL
Northeast	3.18	1.87	2.82
Lake	21.58	12.55	19.11
Corn Belt	51.44	58.26	53.30
North Plains	16.90	16.20	16.71
Appalachia	4.01	2.39	3.57
Southeast	0.98	0.73	0.91
Delta	0.08	0.45	0.18
South Plains	0.31	5.74	1.80
Mountain	1.24	1.17	1.21
Pacific	0.30	0.57	0.37
Unallocated		0.06	0.03
USA TOTAL	100.00	100.00	100.00

	1984 ON-FARM	1984 OFF-FARM	1984 TOTAL
Northeast	3.40	1.98	2.87
Lake	24.17	12.59	19.85
Corn Belt	46.90	52.83	49.11
North Plains	18.62	19.84	19.08
Appalachia	3.04	2.27	2.75
Southeast	1.03	0.81	0.95
Delta	0.09	0.63	0.28
South Plains	0.36	6.62	2.70
Mountain	1.90	1.42	1.70
Pacific	0.48	0.94	0.65
Unallocated	0.00	0.06	0.06
USA TOTAL	100.00	100.00	100.00

TABLE 3.--Continued

REGION/STATE	1985 ON-FARM	1985 OFF-FARM	1985 TOTAL
Northeast	4.04	2.53	2.99
Lake	20.52	10.93	17.95
Corn Belt	51.87	57.68	53.43
North Plains	15.63	15.84	15.69
Appalachia	4.62	3.34	4.27
Southeast	0.97	0.99	0.98
Delta	0.12	0.93	0.34
South Plains	0.37	4.43	1.46
Mountain	1.40	1.20	1.28
Pacific	0.47	1.70	0.80
Unallocated	0.00	0.42	0.82
USA TOTAL	100.00	100.00	100.00

	AVERAGE FOR 3 YEARS		
	ON-FARM	OFF-FARM	1983-1985 TOTAL
Northeast	3.54	2.13	2.90
Lake	22.09	12.03	18.96
Corn Belt	50.07	56.26	51.95
North Plains	17.05	17.29	17.16
Appalachia	3.89	2.67	3.53
Southeast	0.99	0.84	0.94
Delta	0.10	0.67	0.27
South Plains	0.35	5.60	1.98
Mountain	1.51	1.26	1.40
Pacific	0.41	1.07	0.61
Unallocated	0.00	0.18	0.30
USA TOTAL	100.00	100.00	100.00

Table 4. PEANUT STOCKS

Report Date	Farmer Stock (Inshell)	Roasting Stock (Inshell)	Shelled Peanuts	Total Stocks 1/
		1,000 Pounds		
Jan. 1982	1,876,145	51,141	575,084	2,691,148
July 1982	84,948	45,226	471,023	756,634
Jan. 1983	1,607,022	88,870	627,612	2,530,616
July 1983	51,440	71,799	557,063	864,133
Jan. 1984	1,507,187	48,688	562,786	2,304,380
July 1984	48,382	23,322	435,512	611,311
Jan. 1985	1,892,265	91,684	742,623	2,938,944
July 1985	171,949	67,389	890,979	1,424,340
January Averages				
1982-84	1,668,825	62,900	588,494	2,509,048
1983-85	1,668,825	76,414	644,340	2,591,313

Source: Peanut Stocks and Processing, SRS, USDA.

1/ Shelled peanuts are converted to inshell equivalents for computation of total stocks.

range from 200,000 to 20 million bushels and usually include load-out capabilities of 25,000 to 100,000 plus bushels per hour. Many interior terminals are specifically designed to serve the export market with locations in waterways for barge loading or on major rail lines for loading unit train shipments directly to port terminals. The major function of these terminals and the export terminals they supply is handling rather than storage. By comparison with grain storages, peanut warehouses are considerably less modern. Most are horizontal structures of metal or wood with little provision for aerating the peanuts during storage. Handling facilities for unloading the warehouses are often minimal and the buildings are impractical to seal for proper fumigation.

D. Utilization

The utilization of wheat and corn in the United States consists of three major components --domestic use, exports, and carryover supplies. Domestic uses include food, feed, seed and industrial purposes such as alcohol, laminating adhesives, and starch. Approximately two-thirds of the wheat used domestically is for food, with flour being the principal product derived from the grain(12). In contrast, about 60-65% of the corn production is used domestically, primarily as livestock feed (15). Exported wheat and corn is shipped largely as whole grain with only small amounts marketed in the form of processed commodities. In recent years, about 58% of the U.S. wheat production and 29% of the corn production was exported (Table 5).

The carryover of grain into the new marketing year represents a net addition to the supply available for use. The amount of the carryover, where and how it is stored, and the factors that influence these decisions, have been at the center of agricultural policy debate for many years. Viewed from a biological standpoint, this supply of comparatively static grain provides the storage conditions that can lead to the development of damaging insect populations which in turn directly impact pesticide use in the grain industry. As with the grain crops, peanuts are either used domestically, exported or carried over for future use. Domestic use includes peanut butter, confections and candies, bakery products, snack foods (roasted either inshell or shelled),

Table 5. U.S. CORN AND WHEAT EXPORTS, 1982-1984

Crop	Year	U.S. Exports in 1,000 Bushels	Exports as Share of U.S. Production for That Year (Percent)
Corn	1982	1,920,746	23.3
	1983	1,871,116	44.9
	1984	1,929,921	25.6
1982-84 average		1,907,261	28.7
Wheat	1982	1,498,485	54.2
	1983	1,413,475	58.4
	1984	1,552,122	60.4
1982-84 average		1,488,027	57.6

Source: Economic Research Service, USDA, FATUS (Foreign Agricultural Trade of the U.S.), reports for Jan./Feb. 1984 (1982 data) and Jan./Feb. 1985 (1983 and 1984 data).

oil and animal feed. Carryover edible peanuts must be held in cold storage to preserve flavor and quality thus eliminating the insect problem in these peanuts.

FUMIGANTS REGISTERED FOR USE IN STORED GRAIN AND PEANUTS

Phosphine

Aluminum phosphide formulations, which release hydrogen phosphide (phosphine) gas when exposed to moisture and heat, are now the predominant fumigants used for the treatment of bulk stored grain in the United States and throughout the world. There are seven suppliers of fumigant products based on aluminum phosphide formulations:

Company	Product Trade Name	Source
1. Degesch America, Inc.* Weyers Cave, Virginia	Phostoxin	Federal Republic of Germany
2. Research Product Co. Salina, Kansas	Detia	Federal Republic of Germany
3. Pestcon Systems, Inc. Alhambra, California	Fumitoxin	Peoples Republic of China
4. Bernardo Chemicals Memphis, Tennessee	Gastoxin	Brazil
5. Douglas Chemical Co. Liberty, Missouri	Phostek	Brazil
6. Phos-Fume Chemical Co. Overland Park, Kansas	Phos-Kill	India
7. Midland Fumigant, Inc. St. Joseph, Missouri	"L" Fume	India

* Degesch America, Inc. was recently acquired by the Germany company that markets "Detia" Brand aluminum phosphide.

Degesch America, Inc. imports materials from its parent company in the Federal Republic of Germany and produces the formulated product at their plant in Weyers Cave, Virginia. All other aluminum phosphide products are imported by their suppliers as finished ready-to-use fumigants.

Aluminum phosphide materials are available in the form of tablets, pellets, and powder packed in paper sachets. The amount of active ingredient (aluminum phosphide) in the formulated material ranges from 55 to 60% among the various manufacturers. The solid fumigant material is usually packaged in 3-gram tablets or 0.6 gram pellets. Each tablet produces 1 gram of hydrogen phosphine and each pellet 0.2 grams. Formulations packaged in sachets contain 34 grams of material and produce 11 grams of phosphine. To control the rate of release of phosphine, aluminum phosphide is formulated with other compounds such as ammonium carbonate, aluminum stearate, calcium oxide, urea, and edible paraffin which modify the rate of release and lowers the combustibility of the mixture. In some formulations carbon dioxide is given off in the reaction to help retard this problem.

Manufacturers of aluminum phosphide fumigants indicate that there is a delay before phosphine is evolved in large quantities from commercial formulations--usually one to two hours with pellets and two to four hours with tablets before dangerous amounts of phosphine are released. The time required for release is much shorter in warm high moisture grain and much longer in dry cold grain. With grain temperatures above 60°F (15°C), decomposition of formulation should be nearly complete in three days. With low grain temperatures and dry grain, release of the gas may be slowed significantly and concentrations effective against all life stages of insects may never be obtained.

Aluminum phosphide formulations that are in the vapor (gas) phase act upon storage pests. Distribution of phosphine gas in bulk grain is generally dependent on the application or placement of pellets or tablets throughout the grain bulk by adding them to the grain stream during bin filling or by using a 5-foot hollow tube equipped with a hinged flap designed for probing the material into the grain. Tablets are placed in vertical tiers within the grain by inserting the probe fully into the grain and dropping a tablet into the probe at each one-foot interval as the probe is withdrawn. The last tablet in the tier is usually placed about 6 inches below the surface.

Recommended dosages for the various phosphine-producing fumigants are similar. The actual amount of hydrogen phosphide involved in the treatments may vary considerably depending on whether tablets or pellets are used and the type of storage structure. Because phosphine distribution is not materially affected by sorption difference between various commodities, application rates are based primarily on types of storage structure as follows:

Types of Storage	Grams Hydrogen Phosphide/1,000 bu
Upright concrete or metal silos	24-150
Metal farm-type bins	40-180
Flat storage	55-180
Box cars	50-180
Barges	Same as land-based structures

The basic method of applying phosphine-producing fumigants in silo type storages is by the use of an automatic dispenser that drops the solid material into the grain as the grain moves on a belt to storage. Flat storages are generally fumigated by manually inserting the solid material into the grain by using a hollow probe. In some instances where overhead areas of shallow depth storages are particularly gastight, the material may be broadcast over the surface of the grain and "stepped" into the grain.

The time involved and the number of workers used to apply phosphine fumigants vary with the type of structure treated. For silo fumigations, the time of application continues until the bin is filled and is, therefore, dependent on the handling capacity of the elevator. For flat storage, or in any space where people are applying the fumigant, the time available for application is limited by the available time between exposure of the fumigant formulation to air and the initial evolution of the phosphine.

For silo fumigations the number of applicators is generally limited to one or two persons to fill, monitor, and adjust the automatic dispersing equipment. When the aluminum phosphide is applied manually in flat storage fumigations, a number of applicators may be required to ensure that application of the material is completed before significant amounts of the phosphine are evolved.

A recent technique developed for application of phosphine to bulk stored grain involves the use of plastic fabric blankets containing bags of aluminum phosphide. The bag blankets are packaged in sealed containers and on application are removed and rolled out over the surface of the grain.

Treatments by this method require tightly sealed storage structures and extended periods of exposure time to allow for penetration of the phosphine through the grain mass. Another development in phosphine applications and distribution, particularly in upright storages, involves the use of a fan-duct arrangement that permits recirculation of the gas through the grain as it is released from a central application point usually near the grain surface. Because most peanuts are stored in horizontal structures with relatively shallow depths compared to upright grain silos, the most common method of phosphine application in bulk peanuts is by the hollow probe method.

Methyl Bromide

Methyl bromide is a gaseous fumigant marketed as compressed liquidfied gas in cans or cylinders. The principal supplier of methyl bromide used for agricultural purposes is Great Lakes Chemical, West Lafayette, Indiana.

Methyl bromide is formulated as 100% methyl bromide and with 0.5 to 2.0% chloropicrin added as a warning agent. It is packaged in 1 to 1-1/2 lb. cans and in cylinders ranging from 50 to 1,500 pounds each. Methyl bromide is nonflammable, penetrates grain well and provides a very rapid kill of insect pests.

Application of methyl bromide to grain by simple gravity penetration often results in unsatisfactory distribution throughout the grain mass. To improve the distribution, methyl bromide is generally applied to bulk grain by utilizing existing grain aeration systems to push or pull the fumigant through the grain. Distribution of the gas is accomplished either in a single-pass method in which the fan is operated for the time calculated to produce one complete air change within the stored commodity or a provision is made to recirculate the air-gas mixture drawn or pushed through the grain mass. This may be accomplished by using a flexible return duct or by connecting an adjacent tank to serve as a return duct. The fan is operated for the time estimated to produce two or more air changes within the commodity (19). Following exposure periods of 24 to 48 hours, the aeration system is used to exhaust the fumigant from the treated commodity. Both upright tanks and flat storage are treated by variations of the forced distribution principle (26) (28).

Methyl bromide is applied directly from the cans or cylinders in which it is purchased and, because of its relatively high vapor pressure, no additional propellant is required. Scales for weighing the methyl bromide cylinders are used to measure the amount released. Rates of application are generally in the range of 2 to 4 pounds per 1,000 bushels of grain depending on the amount of air space present above the grain surface.

Methyl bromide is not generally used in the fumigation of farmers stock peanuts, Leesch et al. (16) reported sucessful treatment of large (57,570 M3) warehouses in which the gas was released above the peanuts and circulated through the overhead space by fans. Distribution through the peanuts relied on gravity penetration. Bromide residues resulting from the treatment did not approach the 200 ppm tolerance level permitted on peanuts.

Methyl bromide is commonly used on shelled peanut stocks in transportation containers (box cars or trucks).

Chloropicrin

Chloropicrin (tear gas) is a nonflammable liquid fumigant that vaporizes to a gas on exposure to air. It is added to other fumigants as a warning agent and is marketed in pressurized and nonpressurized containers as a space, grain, and soil fumigant. Due to its relatively low vapor pressure (23.8 mm Hg @ 25°C and 10.37 mm Hg @ 10°C) and corrosive action on metals, chloropicrin was marketed primarily in glass bottles and applied as a liquid fumigant. The U.S. supplier of chloropicrin to the agricultural market is Great Lakes Chemical, West Lafayette, Indiana.

Chloropicrin is now packaged in a variety of containers including one-pound bottles, 3-1/2 and 13-1/2 lb. plastic containers, 2 to 70 lb. non-pressurized cylinders, and 100 to 375 lb. cylinders equipped for pressurization. In addition to recirculation, several variations of the gravity penetration method are recommended for the application of chloropicrin to bulk grain. One method is to introduce a prorated portion of the total dosage directly into the grain stream with an aliquot of chloropicrin applied for each 1/2 foot or less of grain depth as the grain is loaded. Recommended dosages range from 2-1/2 lb/1000 bu. for wheat to 4-1/2 lb/1000 bu for sorghum. Another method is to pour chloropicrin through probes inserted into the grain using one probe for each 15 to 20 square feet of grain surface. It is also recommended that grain near the bin surface be treated by applying chloropicrin to burlap bags spread flat on the grain surface. Chloropicrin is also recommended for treatment of the plenum area beneath false-floored bins where grain dust and debris collects and forms a breeding site for insect pests (21).

Because chloropicrin is heavily absorbed by grain during treatment, long periods of aeration are required to remove the odor and resulting tearing effect following fumigation. Concentrations as low as 1 ppm produce intense smarting of the eyes. Continued exposure may cause serious lung injury.

Chloropicrin is not recommended for use on farmers stock or shelled peanuts.

REGULATORY, ECONOMIC, AND MARKETING FACTORS THAT AFFECT THE USE OF PESTICIDES IN GRAIN AND PEANUTS

General

A number of key government and industry regulations, guidelines, and marketing policies interact within the U.S. grain industry to establish the biological and economic consequences of insect infestations in grain. In turn, the nature of these consequences and the degree of penalty they impose on the system directly impacts the pest management strategy used to address the problem. For example, the extensive insect prevention and control practices employed by the milling industry are a direct reflection of FDA's defect action levels for insect related factors of 50 insect fragments per 50 grams of flour and 32 insect-damaged kernels per 100 grams of wheat. In contrast, the current allowable insect tolerances in FGIS's standard for the special grade "weevily" are comparatively lenient on insect activity in bulk grain, especially when grading corn and other feed grains. Furthermore, the market impact of the "weevily" designation is often not realized until the official grading of grain at export. As grain moves through the market system from country elevator to port terminal fumigation may not be necessary if infested lots are sufficiently blended with uninfested grain to bring the insect population within allowable limits. When such blending is not practical or desirable, the most readily available remedial treatment for rapid disinfestation is chemical fumigation.

In grading or classing peanuts insect damage is listed as "worm cuts", which reduces the grade the same as rotten peanuts. If the total damaged kernels (including insect damage) exceed 2 percent the peanuts are normally diverted into oil and animal feed rather than edible use for human consumption. Insect fragments are not tolerated in peanut products, therefore, if a processor receives a lot (shipment) of shelled peanuts which is infested they often reject these peanuts, returning to the sheller or handler at the handler's expense, where they may be fumigated and/or cleaned to remove insects.

FGIS - Evaluation of the Insect Infestation Issue

In recent years, reliance by the grain industry on the axiom that "dilution is the solution" has been less successful, partially due to the increased volume of infested grain entering the market system from farm stored grain and partially due to the growing concern about insects by the grain buyer. These concerns have led to an indepth evaluation of the infestation issue by FGIS that has resulted in two reports of special significance: FGIS Insect Infestation Task Force Report: Grain Infestation, a Problem/Solution Report, June 26, 1985, and the FGIS Advisory Committee Report of the Subcommittee on Insect Infestation, October 8, 1985. The task force report addressed FGIS's responsibilities in the national inspection system and recommended changes to

improve FGIS's detection, identification, and certification of insects in grain. The Subcommittee reviewed the task force report and issued a series of recommendations on specific changes in the guidelines used to classify grain "weevily". The proposed changes would gradually lower insect tolerances over a "transition" period that would allow time for the grain industry to adjust to the higher level of insect control required. The delay in reducing tolerances was considered necessary because of the loss of liquid grain fumigants and possible further restrictions against other pesticides used in grain.

In a Federal Register Notice (7) dated July 7, 1986, the Federal Grain Inspection Service invited public comment on three suggested changes to (insect) tolerances and grading factors relating to insect infestation of grain. Specifically, the suggested changes would: (1.) Set the same tolerance for insects for all of the U.S. grain standards (all grain would be treated the same), (2.) Treat all types of insects injurious to stored grain with equal weight in the established tolerances (all species would be treated the same), and (3.) Create a separate grade factor in the wheat standards to limit insect damaged kernels (kernels fed upon by insects would no longer be considered simply "insect chewed, but not damaged"). These proposed changes whether adopted singularly or collectively would significantly increase the economic consequences of allowing stored grain to become infested.

Grain industry representatives attending a series of workshops organized by the North American Export Grain Association issued a consensus report (1) on the "findings and recommended changes of U.S. Grain Standards, Practices and Procedures". In reference to the insect issue, the report concluded that "infestation is, in fact, a contributing factor in both foreign and domestic customer complaints, both from an under reporting and a quality viewpoint. The report recommended support of FGIS efforts to redefine the term "weevily", establish a procedure for specifying insect damaged kernals, improve methods for detecting hidden infestation and study the market impact of reporting dead insects.

The full impact of reduced insect tolerances on future pesticide demand is difficult to assess. It is likely, however, that changes in the "weevily" classification will bring increased pressure throughout the marketing system to expand and improve control of insects in grain. Because pesticides continue to be the principal component of pest management practices in stored grain, it is reasonable to assume that their overall use may increase.

ASCS - Farm Loan Policy on Insect Infestation

A policy guideline employed by the Agriculture Stabilization and Consevation Service (ASCS) that addresses insect infestation in grain under farm loan will also play an increasing role in mandating pest control in grain. Grain under consideration for long term storage in grain reserve programs is subject to inspection prior to approval. If live insects are detected in the

grain, the loan is witheld and the producer advised that the insect problem will have to be corrected before the grain can enter the program. On notice by the producer that the problem has been corrected, a second inspection may be conducted or the loan could be placed on a list for spot check during the following storage year. If an infestation is found during the spot check, the loan is subject to immediate recall. Many state ASCS offices are reporting record applications for short term farm storage loans as a result of high production and low market prices for grain. If similar conditions persist next year and adequate precautions are not taken by producers to treat their grain with a residual grain protectant at the time the grain is binned, the need for remedial fumigation treatment will likely increase significantly in order to meet the insect requirements under extended storage programs.

Market Discounts for Insect Infestation

One of the more direct economic links to insect infestation is the growing industry practice of discounting producers if live insects are detected in grain they deliver to the elevator. Harein, et al. (9) reported that the average discount for selling grain that was both moldy and insect-infested during 1984 in Minnesota was 17¢ per bushel for corn and 33¢ per bushel for wheat. In a survey of 370 elevator managers across mid-western and praire states, it was found that about 75% discount producers from 1 to 20 cents per bushel (average 5.2¢) if live insects are observed in the grain (30). The discounts are typically applied against the price paid per bushel, but may also be assessed as a charge for "fumigating the grain." In a follow-up study addressing elevator market policy on insect infestation, managers across Kansas, Nebraska, and Oklahoma agreed that while no established policy exists to refuse infested grain only 12% of the managers indicated they would always accept infested grain without any penalty. They also reported that the presence of any live insect was the primary factor triggering the discount with the number and "kind" of live insect secondary in importance. This would suggest that fungus beetles and other high moisture insects are just as likely to be a factor in contributing to the application of a discount as are insect species that actually feed on grain. Furthermore, when asked about the presence of "dead" insects in the grain, about one-fourth of the managers indicated they would

likely discount the grain because the "bugs" were evidence that the grain had probably been damaged and might require cleaning before heading out to the next point in the market chain. This response suggests that producers who allow their grain to become infested could suffer a double penalty--the cost of fumigation to control the insects and a discount for the dead and fragmented insect bodies remaining in the grain as readily visible evidence of the infestation. Finally, nearly two-thirds of the elevator managers at the county elevator level reported that they were consistently discounted for insects by their regional market buyers and most were convinced that the penalties applied against them were more strict than those they applied against the producer. Clearly, insect discounting has become an inherent economic factor that manifests itself throughout the grain market system, from farm to processor and to export.

The anticipated potential value of the grain will also make a difference in the effort that storage managers make to keep it free of insects. The best way to increase grain prices over any extended time is to increase export markets. Unfortunately, complaints about export grain quality have increased from 6 in 1984 to 70 in 1985.

EPA - Impact on Pesticide Market

Direct EPA regulatory actions against EDB and other liquid fumigant components have had an obvious impact on pesticide use in grain. What is not generally recognized, however, is the widespread influence EPA exerts on the grain pesticide market long before any final regulatory steps are taken. This occurs because the total pesticide market in stored grain is very small in comparison with other agriculture chemical markets such as field herbicides, insecticides, and fertilizers. The market is further characterized by the limited number of chemicals approved for use and the intense competition among grain pesticide suppliers. This restrictive post-harvest pesticide market is spread over a broad grain storage industry composed primarily of a storage and marketing segment dominated by large supplies of grain on the farm and a growing concern about insect problems at export. There is also a processing segment that has become hypersensitive to pesticide residues at the same time they are

increased insect activity in the grain they process. It is within this context that data call-ins, RPARS (Special Reviews), and rumors are translated into shifts in fumigant market shares, restructured or abandoned pest management strategies and a pervasive feeling of uncertainty about "what's next on the list". Thus, at the same time EPA is actively seeking information on pesticide use in grain through contracts with consultants, Special Review activities, and authorized statutory methods, they are indirectly altering the same market (Appendix A).

Fumigant Residues

A survey conducted by the Food Marketing Institute on consumer attitudes towards foods revealed that concerns about pesticide residues have largely replaced previous concerns about food additives in general or such traditional food components as cholesterol, sugar and salt. The heightened awareness of pesticide residues likely had its foundation in the aftermath of the publicity about EDB in late 1983 and early 1984 in which fumigant use came under close scrutiny both domestically and among foreign grain buyers. Although only a few countries actually added new specifications or conditions on these grain purchases because of possible EDB contamination, the Federal Grain Inspection Service began a testing program in 1984 to examine raw grain and processed commodity samples for the presence of EDB, CCl_4 and MBr. Such data was provided on request by the inspection applicant. In some instances the purchaser required the tests.

Domestically, the residue situation bordered on the chaotic during the periods preceeding and immediately following the suspension of EDB by EPA. Nightly accounts in the news media, pictures of milled products being removed from the grocery shelves, and the reporting of "contaminated" products at residue levels of questionable analytical reliability took a heavy toil in consumer confidence in food safety, placed much of the cereal food industry in a defensive position and was likely a major factor in ending the procrastination by EPA on the entire fumigant registration process.

EPA's data-call-in requests on virtually all remaining fumigant components were interpreted by many in the grain processing industry as a signal that the EDB residue furor could easily be repeated in the future with other fumigant components. As a result, several major grain processors began analyzing their grain supplies for fumigant residues and also included fumigant residue specifications in their grain purchase contracts. These actions were taken several months prior to an agreement by manufacturers to stop formulation of liquid fumigants at the end of 1984. While it is not possible to determine how much influence such actions had on the decisions made by the fumigant manufacturers, it is evident that the manufacturers found themselves in a "no-win" situation in which the market for liquid fumigants already eroded by increased use of phosphine materials was being further restricted by changes in the purchasing policies of the grain processors. These industry policies eventually culminated in a position letter from the Millers' National Federation (March 1, 1985) (Appendix B) to various state pesticide coordinators advising them of the milling industry's position that "they would prefer the use of liquid fumigants on wheat be voluntarily stopped immediately."

EPA-Label Improvement Program

On November 15, 1984, EPA issued PR Notice 84-5, "Label Improvement Program for Fumigants" which was developed to "help minimize occupational exposure to fumigants". Changes that will be required on the label to better define user information, warnings, and necessary precautionary measures will likely result in the professionalization of this type of remedial pest management practice. Three features of this program will impact immediately on what fumigants are used and who uses them throughout the grain marketing system. First, the revised label will direct that two "trained" persons be present during the principal fumigant operation. Second, the use of approved respiratory protection devices (probably self-contained breathing apparatus) would be required when the concentrations of the fumigant exceed prescribed levels or if the concentrations are unknown. Third, specified direct-reading detector devices would be required to monitor fumigant concentrations to prescribed levels as a condition of reentry or transfer of treated grain.

Liability Insurance Costs

Tighter control on fumigant application procedures through the labeling process and an expanded format for identifying restricted pesticide users will clearly impact both commercial and private fumigators in the future. However, many fumigant suppliers believe the most dominant factor that will affect fumigant use in the immediate future is the rapidly escalating liability insurance costs for pesticide applicators and marketers. With rate increases reportedly as high as 500%, many in the fumigant industry question whether fumigant services particularly in rural areas will be available in the future. The attendant costs in travel and labor involved in servicing farm accounts especially at locations with less than 10,000 bushels of storage presents a situation where the cost of fumigation could be close to the discount penalty for "infested" grain charged to the producer at some points of market. Further escalation in fumigation expenses due to higher insurance rates would likely push the cost of control beyond the current discount levels for insects, thereby creating a negative incentive for controlling insects in farm stored grain.

Annual Postharvest Use of Fumigants in Stored Wheat, Corn and Peanuts

Fumigant Use in wheat and Corn

The fumigant assessment team for stored commodities held a meeting in Kansas City, Missouri on August 27 and 28, 1985, with representatives of the principal U.S. fumigant suppliers and distributors for the purpose of developing a national estimate of fumigant use in the designated commodities (Appendix C). Participants were provided grain production storage and export date as a background against which fumigant use was to be apportionated. No company was asked to provide specific sales data of a proprietary nature, but all were encouraged to share general marketing information that could be collated into

consensus team/industry estimates. Data on the national use of aluminum phosphide, chloropicrin and methyl bromide in wheat and corn developed during the meeting are in Table 6.[1/]

The combined amounts of the three fumigant materials estimated being used annually in the two cereal grains would be sufficient to treat about 18.5% of the total wheat and corn stocks in storage during the marketing year. Individually, phosphine materials account for 85% of the fumigated grain, chloropicrin 9%, and methyl bromide 6%. The combined fumigant materials treat about 48% of the stored wheat, but only 8% of the stored corn. In actual practice, the percentages of fumigated wheat and corn would be reduced by the amount of grain treated more than once as it moves through the market system. Based on estimates of prior "on-farm" fumigations (Table 6), in addition to expected treatment duplications between country elevators and regional terminals it is not unreasonable to assume that at least 20% of the wheat passing through commercial grain storage has been previously fumigated. This would reduce the total wheat stocks treated annually from 48% to 40%. Corn is less likely to have a prior history of treatment as it moves through the commercial storage system in part due to its less frequent treatment at the farm level and also because of its relative late entry into the marketing system where reduced grain temperatures can minimize insect activity. Additionally, insect tolerances are more lenient in corn and the incentive for treatment is less than for wheat. An estimated 5% duplication in fumigation of off-farm corn stocks would reduce the total stocks fumigated annually from 8 to 7.8%. Combining the repeat fumigations estimated for both wheat and corn reduces the overall treatment of the two commodities from 18.5% to 15.0%.

1/ Marketing trends through the first half of 1986 indicate a significant increase in the demand for aluminum phosphide fumigants with some suppliers reporting 30% greater sales compared to the mid year period in 1985. The increased demand is attributed to a combination of factors including a higher carry over of grain stocks, greater insect problems due to climate conditions favorable for insect development, replacement of liquid fumigant stocks with phosphine materials, and increased concerns about the future consequences of marketing "infested" grain.

Table 6. Annual Postharvest Use of Fumigants in Stored Wheat and Corn

Commodity/ Location	Aluminum phosphide					Chloropicrin					Methyl Bromide				
	Kg. used	Percent of total used by commodity and by location	Percent within each commodity used at each location	Bushels treated 1/ (millions)	Percent treated of total bushels stored	Pounds used	Percent of total used by commodity and by location	Percent within each commodity used at each location	Bushels treated 2/ (millions)	Percent treated of total bushels stored	Pounds used	Percent of total used by commodity and by location	Percent within each commodity used at each location	Bushels treated 3/ (millions)	Percent treated of total bushels stored
Wheat															
On-farm	10,780	14	20	119.8	11.4	120,000	30	75	48.0	4.6	10,150	4	5	4.0	0.4
Off-farm 4/	43,120	56	80	862.4	66.5	40,000	10	25	16.0	1.2	192,850	74	95	78.0	6.0
Total	53,900	70	100	982.2	42.0	160,000	40	100	64.0	2.7	203,000	78	100	82.0	3.5
Corn															
On-farm	2,310	3	10	25.7	0.5	180,000	45	75	60.0	1.3	2,850	1	5	1.0	0.02
Off-farm 4/	20,790	27	90	415.8	20.7	60,000	15	25	20.0	1.0	54,150	21	95	21.0	1.0
Total	23,100	30	100	441.5	6.6	240,000	60	100	80.0	1.2	57,000	22	100	22.0	0.3
Wheat and Corn															
On-farm	13,090	17		145.5	2.5	300,000	75		108.0	1.9	13,000	5		5.0	0.1
Off-farm	63,910	83		1,278.2	38.6	100,000	25		36.0	1.1	247,000	95		99.0	3.0
Total	77,000	100		1,423.7	15.7	400,000	100		144.0	1.6	260,000	100		104.0	1.2

1/ Average aluminum phosphide dosage = 50 g/1,000 bu wheat and corn.
2/ Average chloropicrin dosage = 2.5 lbs/1,000 bu wheat; 3.0 lbs/1,000 bu corn.
3/ Average methyl bromide dosage = 2.0 lbs/1,000 cu ft (800 bu) wheat and corn.
4/ 20% of wheat off-farm stocks and 5% of corn off-farm stocks estimated as previously fumigated.

No data on liquid fumigants was included in the tabular material presented in Table 6. Supplies of liquid fumigants remaining in the market at the time of the meeting were estimated at between 200,000 to 300,000 gallons which represents only 10 to 15% of the 2 million gallons used annually prior to cancellation of EDB and the subsequent data call-in request issued by EPA on other liquid fumigant components. If the remaining liquid mixtures were applied exclusively to wheat and corn, the volume of grain treated would be less than 1.5% of the total stocks in storage.

Aluminum phosphide clearly dominates other fumigants for the treatment of wheat throughout the marketing system and for the treatment of corn in off-farm storages. Relatively little corn is fumigated while stored on the farm, however, the 60 million bushels estimated as fumigated with chloropicrin, represents more than twice the volume treated with phosphine materials. This apparent preference for chloropicrin in farm stored corn is further evidenced by early 1985 marketing trends indicating increased orders for chloropicrin from distributors in the corn belt area (5). The diminished role of methyl bromide in fumigating commercial grain storages and its recognized limited use in farm storage is reflected in the low volumes of the material used annually in stored wheat and corn (Table 6). Like aluminum phosphide, methyl bromide use is heavily concentrated in wheat with nearly three-fourth of the gas applied to commercial off-farm storages. Methyl bromide is expected to remain a professional fumigator's chemical. Its future is likely to be influenced by the extent to which grain handlers move toward hiring professional fumigators rather than fumigating themselves.

Fumigant Use in Peanuts

Annual pesticide use in stored peanuts is shown in Table 7. Liquid fumigants have never been used to any extent on peanuts (in-shell or shelled). Traditionally methyl bromide has only been used on shelled peanuts in the transportation containers (box cars or trucks) with occasional fumigation of in-shell peanuts in warehouses or silos which could be adequately sealed for fumigation. Aluminum phosphide has gained acceptance as a fumigant for in-shell peanuts since the slower release and good penetration capabilities allow its use in some structures that are not suitable for methyl bromide fumigation without recirculation. Aluminum phosphide is also used in transportation containers on shelled peanuts.

Table 7. Pesticide use and cost for stored peanuts, inshell and shelled

Pesticide (Active Ingredient)	Quantity of peanuts treated: Percent of source	Source 1/	Pounds (1,000's)	Application rate per 1,000 pounds	Total quantity of pesticide	Treatment cost (Dollars)
Phosphine	20.00	A	332,690	62.50 grams	20,793,138 grams	186,473
Methyl Bromide	30.00	C	1,114,153	0.75 pounds	835,615 pounds	624,483
Malathion	65.00	C	2,413,998	0.02 pounds	50,250 pounds	593,843
Totals			3,860,841			1,404,799

1/ A = Jan. 1 farmer stock
B = Jan. 1 shelled stock
C = Total production

C. Fumigation Costs

Most fumigant materials are marketed from the basic manufacturer through a network of distributors, dealers, and retailers. A retail markup of 30% above wholesale cost is typical with the final cost to the user modified by volume purchased and competition among suppliers. Pricing in the highly competitive phosphine market appears to be the most volatile with the overall trend during recent years toward reduced retail prices. In contrast, chloropicrin has slowly increased in price to a point at which cost for chloropricrin treatment at recommended dosages are now similar to costs previously associated with the application of liquid fumigants. Methyl bromide prices have remained fairly constant over the past several years, however, unit costs for methyl bromide sold as a soil fumigant appear to be somewhat lower than methyl bromide marketed into the grain industry.

Retail costs for fumigants generally fall within the following price range:

Aluminum phosphide	= 6.0¢ to 10.0¢ per gram of phosphine produced
Chloropicrin	= $3.00 to 7.00 per pound
Methyl bromide	$0.90 to $1.50 per pound

Treatment cost (for fumigant materials only) are compared in three types and sizes of storage:

Fumigant	Farm Bin (10,000 bu) ¢ per bushel	Elevator Silo (20,000 bu) ¢ per bu	Flat Storage (100,000 bu) ¢ per bu
PH_3[1/]	0.73 - 0.90	0.30 - 0.50	0.60 - 1.0
chloropicrin[2/]	0.73 - 1.25	0.75 - 1.25	0.75 - 1.25
methyl bromide[3/]	0.23 - 0.38	0.23 - 0.39	0.34 - 0.56

1/ PH_3 per 1,000 bu = 90g farm, 50g elevator, 100g flat.
2/ Chloropicrin per 1,000 bu = 2.5 lbs all storages.
3/ Methyl bromide per 1,000 cu. ft. = 2.5 lbs farm, 2.0 lbs elevator, 2.5 lbs flat.

The total cost of fumigating grain may be divided into five principal components with the base price of fumigant materials representing only one segment:

1. Unit Cost of fumigant materials.

2. Amount Used for different commodities and types of storage.

3. Application costs: labor, specialized equipment, sealing, travel.

4. Regulatory expenses: training and certification, safety equipment, insurance.

5. Profit (commercial applicators).

In the past, do-it-yourself farmer or elevator employee fumigations offered a significant economic advantage over professional fumigation services. Higher unit costs for fumigant materials were more than offset by lower application costs and elimination of the profit factor. Today, the economic rationale for private fumigation is less clear. Prices for some fumigant materials purchased in small quantities are lower and savings in application costs remain an advantage, but new requirements under EPA's Label Improvement may drastically alter the total "cost" of privately fumigating stored commodities. Purchasing the necessary respiratory equipment and analytical devices required under the program is fully warrented from a safety standpoint, but such an expenditure by individual farmers or small country elevator operators who fumigate only once a year or less would have to be measured against the option of hiring a professional fumigator. Even if total costs should continue to favor private applications, the occasional fumigator must ask himself if the personal risks involved in such treatments are worth the potential savings. In addition, both the private and the professional fumigator will have to become more familiar with the many variables that can reduce the effectiveness of a fumigation and be prepared to make the necessary modifications as required to obtain satisfactory results without the excessive or improper use of fumigant chemicals.

Commercial fumigation services encompass a wide range of operations from national or regional franchised companies to small privately owned firms that service a limited area. In some lightly populated rural areas no services are currently available and it is questionable whether such service may be provided in the future. Travel expenses to these areas would likely make the cost of treatment prohibitive and insufficient business volume discourages the development of local fumigation companies.

Commercial fumigation contracts reflect a wide range of options as to services provided, treatment "guarantees" and costs. Some contracts provide essentially a pest management service that includes inspection--monitoring the grain temperature and moisture, perimeter spraying with a residual insecticide around storage sites, and fumigation as required. Others may be a simple "one-shot" fumigation of a specific storage structure with an implied guarantee as to "satisfaction" with the results obtained. Still, others may offer only a flat rate charge per bushel treated with no implied recourse with respect to the efficiency of the fumigation. Spot checks of commercial services show fumigation costs ranging from 0.6¢ to 5¢ per bushel. Fumigation charges in many rural areas range from 2.5¢ to 5¢ per bushel and are based primarily on the distances required for travel to the fumigation site. Commercial fumigators report that the type of grain storage being fumigated and the labor and sealing preparations required for proper treatment are often the dominate factors establishing fumigation costs in commercial storages, with the kind of grain fumigated and necessary dosage adjustments of secondary importance. The lowered price for commercial fumigations generally involve a shared arrangement in which the fumigant service provides the fumigant, technical expertise, application equipment and supervision and the grain company provides the necessary labor for sealing and fumigant application.

VII. ALTERNATIVE PEST MANAGEMENT PRACTICES

Several alternative methods for controlling insects in stored grain are available, but none possess the same distributional characteristics, toxic properties, and relatively low cost as fumigants. Modified atmosphere treatment

of grain involving alteration of the proportions of the normal gaseous constituents of air (oxygen, nitrogen, carbon dioxide) to provide an insecticidal atmosphere represents the most likely direct substitute for chemical fumigation of grain. Technologies for producing, handling and supplying modified atmospheres have been developed and studies have confirmed the effectiveness of these atmospheres and their compatibility with high quality maintenance of stored commodities (2), (3), (13), (29). Also, EPA established an exemption from the requirement of a tolerance for modified atmospheres on all raw and processed agriculture commodities (Federal Register, November 17, 1980 and June 25, 1981). Several industrial gas companies have registered labels for CO_2 use in disinfesting bulk grain and a mobile inert atmosphere generator is being marketed to provide onsite generation of a combustion gas composed of less than 1% O_2, 10-12% CO_2, with the balance principally N_2. Adoption of modified atmosphere technology, however, may require: (1) a substantial restructuring of existing storage facilities to improve their gas-tightness (a step also made necessary by the loss of liquid fumigants and increased relevance on phosphine materials which are difficult to contain within the treated storage), (2) capital investment in specialized equipment required to generate or vaporize the modified atmosphere, and (3) the establishment of new and more highly sophisticated operational procedures that involve more than probing tablets, pumping a sprayer or opening a cylinder.

The most practical alternative control practice is to prevent insects from developing into damaging populations that require fumigation. Preventive measures include sanitation practices to clean out left over grain and remove harborage sites prior to loading grain, pre-bin spraying with a residual insecticide, application of a grain protectant to the grain as it is placed into storage and aeration of the grain to lower temperatures to levels that restrict insect activity. The use of grain protectants has several advantages over fumigants: they persist for extended periods at concentrations lethal to storage insects; they are generally safer to supply; and they require little specialized application equipment (8). Commercial grain protectants are recognized internationally with established (FAO/WHO) residue tolerances in raw cereal grains and in milled products made from treated grain. With increasing restrictions on grain fumigants, their use may not be just a matter of choice

in the future. If infestation and the resulting loss in quality cannot be tolerated and if alternative control measures offer no practical or cost relevant solution, chemical control achieved through the application of a residual insecticide may be the only realistic solution.

For nearly thirty years the only two chemical insecticides approved in the U.S. for direct application to grain were synergized pyrethrins and malathion. EPA, however, has recently taken action on two new grain protectant materials, chlorpyrifos-methyl (Reldan) and pirimiphos-methyl (Actellic). Each of these organophosphorous compounds has an established reputation as an effective residual insecticide for stored grain pests including such species as the Indianmeal moth, which is resistant to malathion (4), (14), (20), (22), (23). Chlorpyrifos-methyl was granted registration by EPA in June 1985 (EPA Reg. No. 7501-41) for domestic and export use on wheat, grain sorghum, barley, oats and rice. Approval for use on corn was not granted at that time pending development and review of additional residue data. Suppliers of this product anticipate approval for use on corn to be granted in September 1986. Pirimiphos-methyl was registered in the fall of 1984 (EPA Reg. No. 10182-87) to treat corn, rice, wheat and grain sorghum intended for export only. Manufacturers of pirimiphos-methyl supplied additional residue data required by EPA and registration for domestic use in corn and grain sorghum was approved on July 31, 1986 (EPA Reg. No. 10182-79). Costs for these new materials is estimated at 1 1/2¢ per bushel compared to about 1/2¢ per bushel for malathion.

Application to EPA for registration of a third grain protectant, Sumithion (fenitrothion) was made by the manufacturer in August of 1985. This chemical is the principal grain insecticide used in Australia. No action on the petition has been reported by EPA.

Irrespective of their demonstrated effectiveness and low costs, the previously registered grain protectants, synergized pyrethrins and malathion have not been extensively used in the U.S. grain marketing system. Storey, et al. (31), (32), found that only 7.7% of the corn and 11.6% of the wheat arriving at port terminals in the U.S. and 4.2% of the oats, 8.2% of the corn and 14.6% of the wheat stored in farm bins across 27 states contained biologically active deposits of malathion. Whether or not the new grain protectant materials with their higher costs, but improved effectiveness, will receive widespread use is uncertain.

Aspiration of grain to lower dockage levels to provide a less favorable habitat for insect development and aeration to cool grain to limit insect activity are examples of recommended nonchemical elements of a total pest management program. They are not, however, direct substitutes for chemical disinfestation of grain. Nevertheless, their proper use can reduce the amount of fumigant required by improving its distribution through the grain mass and by extending the residual life of protectant chemicals through lower grain temperatures.

Several non-chemical technologies have been investigated in an effort to reduce or eliminate the dependence on chemical pesticides for the control of grain storage pests. Microbial control of insects involving the utilization of microorganisms and their by-products to regulate insect populations has shown great potential for control of field pests, but that potential has not been realized in stored grain. The bacterium, Bacillus thuringiensis, has been prepared in commercial formulations expressly for moth control, but results obtained with this spore material has been mixed and problems have surfaced with resistance among some moth strains (17), (18).

The hormones and enzymes manufactured by the insect itself to control its development have been synthesized into a new class of insecticides - insect growth regulators. Because vertebrates in general, and man in particular, are so distant genetically and morphologically, these specialized compounds have shown no adverse side effects. Their principal drawbacks appear to be high costs, slow action, and the increased precision that would be required for their application to bulk grain. At present, none of these highly complex materials have been registered by EPA for direct application to stored grain nor are any used routinely in grain pest management programs in other major grain producing countries.

One of the most widely publicized forms of biological "control" is the use of insect pheromones. These minute, but powerful chemical substances are a fundamental part of the communication between one insect and another. The value of pheromones in grain pest management programs is in the area of insect monitoring-detection rather than in direct control. They may be used in

conjunction with insect traps to help pinpoint the location and possible source of an insect infestation, thereby improving the timing and efficiency of applied control measures.

Several methods of heating cereal products and bulk stored grain have been investigated, including the use of radiant heating processes such as infrared microwave, dielectric heating and shallow fluidized-bed heating systems for continuous inline treatment during bulk grain handling. None of these sytems has been developed into a commercial operation in the U.S.; however, conventional plant heating systems are being used to raise temperatures to lethal levels throughout an entire processing area for controlling insects within various types of milling equipment (11).

One of the more controversial and least understood alternatives is the irradiation of grain and grain products for insect control. Some generalizations applicable to irradiation are (33):

1. Electron beams, x-radiation and gamma rays from radioactive cobalt or cesium are equally effective in controlling insects in stored grain and grain products at comparable doses of absorbed ionizing radiation.

2. The international standards for irradiated foodstuffs issued in 1980 by the international agency on atomic energy and the WHO-FAO commissions--approved and established the maximum energy level and dose to be used for grain disinfestation.

3. At the level for electron energy used for disinfestation, no radioactive nuclides are formed in the grain.

4. Intermediate levels of irradiation produces sexual sterility of exposed insects--which may be one reason that no evidence has been found that insects develop resistance to irradiation.

Despite these positive attributes, irradiation has made little progress as an integral part of commercial pest management in stored grain. Its cost and the management skill required to apply irradiation technology is clearly out of proportion to the present day cost or penalty for having insects in bulk stored grain. Furthermore, irradiation-like chemical fumigation controls only the existing insect population and provides no protection against reinvasion by insects. Irradiation technology, efficacy and economics are clearly applicable when the target to be controlled is located in a commodity such as meat which has a high value relative to its small mass. It appears to be unrealistic, however, to try and extend this technology to treat insects in bulk grain that is worth less than a nickel a pound and that occupies 1 1/4 cu. ft. for each bushel. Nevertheless, the USSR has built a pilot electron beam accelerator at a port terminal in Odessa, Russia with an operating capacity of between 200 to 400 ton/hour (7,500 to 15,000 bu.). Projecting an annual operating time of 5,000 hours, processing capacity is estimated between 1 to 2 million tons of grain per year (37-74 million bu.). The average put-through for elevators in the U.S. is about 2.3 times the storage capacity per year, thus operating with the Russian parameters would require an elevator with a storage capacity between 16 to 32 million bu. turned over 2.3 times annually. Among nearly 70 export terminals in the U.S., the average storage capacity is about 5 million bu. Adoption of irradiation technology by the U.S. grain marketing system would require a major shifting of grain stocks to large terminal centers that could provide the high put-through volume necessary for cost efficient operation.

Grain protectants, modified atmospheres and the supportive physical actions of aeration, aspiration and sanitation practices represent control alternatives that are either immediately available or are in the process of being integrated into practical control strategies. However, except for the role of pheromones in monitoring programs, biological control schemes have not yet proven successful in bulk grain storage situations and irradiation remains an unlikely control practice in the U.S. grain marketing system. For the short term, therefore, chemical fumigation will continue to play an active and essential role in grain pest management.

IMPACT OF FUMIGANT(S) CANCELLATION

Survey of State Extension Specialists and Regulatory Officials.

Opinions regarding the possible biological and economic consequences resulting from the loss of grain fumigants were obtained from a cross-section of extension specialists and pesticide regulatory officials participating in a National Fumigation and Grain Protectant Training Conference (Feb. 1985, Corpus Christi, Texas). Participants were asked to complete a series of fumigant assessment worksheets in which they were required to reflect on the future of pest management in stored grain following the loss of specific fumigant compounds (Appendix D). Each "loss scenario" involved both on and off-farm situations and requested a judgement response on the use of other fumigants or pest management procedures likely to replace the "lost" fumigant, the effect of the "loss" on the amount of grain treated, the level of insect infestation, and insect discounting at time of grain sale. Finally, a response was requested on the overall impact of each "loss scenario" on grain quality with respect to insect related damage.

A total of 26 worksheets were completed representing responses from 19 states. The following is a summary of the responses received to the loss of specific fumigant compound(s):

1. Loss of (carbon tetrachloride based) liquid fumigants

    a. Nearly all (92-95%) believe the use of solid fumigants would increase in both on and off farm situations.

    b. Over three fourths see an increase in the use of grain protectants and nonchemical controls as a result of the loss of liquid fumigants.

    c. Methyl bromide was expected to increase in off-farm use, but not in on-farm use and chloropicrin was not expected to gain in use in either on- or off-farm positions.

d. Opinion was equally divided between those that believe less grain would be fumigated on-farm with the loss of liquid fumigant and those that believe the amount fumigated would remain the same. Over two-thirds, however, believe off-farm treatments would remain the same.

e. Insect infestation, discounts and grain quality were generally expected to remain the same after the loss of liquid fumigants.

2. Loss of solid (phosphine-producing) fumigants.

a. Responses indicate that the use of liquid fumigants (if available) and grain protectants would most likely increase in on-farm situations and also with the addition of methyl bromide all three would likely increase in use in off-farm situations.

b. Fifteen percent fewer individuals thought grain protectant use would increase in on-farm situations with the loss of solids than with the loss of liquids. Similarly, few individuals thought non-chemical controls would be increased with the loss of solids than with the loss of liquids.

c. Slightly more than one-half of the responses believe that the amount of grain fumigated on the farm would remain the same with the loss of solids or with the loss of liquids.

d. Opinion shifts significantly regarding insect infestation resulting from the loss of solids versus the loss of liquids. Infestations were generally expected to remain the same with the loss of liquids, but with the loss of solids over half believe infestation would increase on-farm and 70% believe infestation would increase off-farm.

e. Insect discounts were also expected to increase with the loss of solids, especially at off-farm locations. Opinion was divided on the quality effect at the farm level between remaining the same and decreasing, but nearly two-thirds believe quality would decline in off-farm locations.

3. Loss of Methyl bromide.

a. Impact from the loss of methyl bromide was believed to be primarily at the off-farm position--with solids, non-chemical controls, and liquids increasing in use. The use of chloropicrin was not expected to change.

b. The amount of grain fumigated, level of infestation, insect discounts, and grain quality were generally expected to remain the same.

4. Loss of chloropicrin.

a. Less than half of the individuals surveyed expressed an opinion suggesting little familiarity with the product.

b. Those responding did not believe that loss of chloropicrin would significantly change the use patterns of the remaining alternatives nor would the loss impact on the amount of grain treated, insect infestation, discounts, or grain quality.

5. Loss of Liquids and Methyl Bromides.

a. All believe this action would increase the use of solids in both on- and off-farm positions.

b. The use of non-chemical controls were expected to increase in both on- and off-farm positions. More individuals expressed this view after the loss of both materials than previously indicated this action with the loss of any single fumigant compound.

c. The use of grain protectants was expected to increase in both on- and off-farm situations by similar response percentages as previously expressed for the loss of either liquid or methyl bromide individually. No additive effect from the loss of both fumigant materials was apparent.

d. Chloropicrin was expected to gain in on-farm use, but not in off-farm use.

e. Opinion about equally divided between those who believe each factor would remain the same and those who think the amount of grain fumigated would decrease, particularly at the farm level; insect infestation and discounts would increase and, grain quality would decrease.

6. Increase Reliance on Grain Protectant and Nonchemical Controls Resulting from Loss of All Fumigant Materials.

   a. Nearly all responses indicate insect infestation would increase--indicating little confidence that non-fumigant control measures would be sufficiently effective to prevent insect infestations.

   b. Responses indicate a strong perception of the link between dependence on a few residual pesticides and the risk of increased development of insect resistance.

   c. Over three fourths of the responses indicate a reduction in quality of grain in both on- and off-farm positions resulting from the loss of all fumigant materials.

Although opinions varied as to the impact of the loss of specific fumigant materials, there was a clear indication in the responses that fumigants are considered a necessary pest management tool and their loss would adversely affect the quality of grain in storage. Most respondants believe the loss of individual fumigants would increase the use of grain protectants and

nonchemical controls, but expressed little confidence that non-fumigant control measures alone would be sufficiently effective in preventing insect infestations if all fumigant materials were discontinued. This view was, perhaps, strengthened at the time of the survey because two new grain protectant chemicals, chlorpyrifos- methyl (Reldan) and pirimiphos-methyl (Actellic) were still under consideration for registration by EPA. Furthermore, many of the nonchemical technologies indentified by EPA as "Practices available for insect control on harvested grains" (6) such as modified atmospheres, temperature manipulation, and gamma radiation have yet to be integrated into practical and cost effective pest management strategies, especially at the farm level.

ECONOMIC ANALYSIS

This economic analysis uses partial budgeting to show the changes in insect control costs and quality losses resulting from banning one or all stored grain fumigants: phosphine, chloropicrin, and methyl bromide. The team projected changes in pest control practices under each potential ban from which changes in pest control costs were estimated. Estimates of grain quantities currently treated are deduced from fumigant uses, as discussed earlier, and typical application rates. The team also projected the quantity of grain discounted for live insects and further insect-caused quality losses. Because there is a lack of data, the estimates of quality losses are based on expert opinion rather than statistical analysis. As a result, these are gross estimates that give a general idea of the economic loss of removing one or all stored grain fumigants from the market.

Due to the small percentage changes in quantities of commodities, average prices are assumed unchanged if fumigants were removed from the market. As a result, all losses are assumed to be borne by the storer who would fumigate the insect infestation.

Wheat and Corn

While there is a range in the cost of applying each fumigant and the alternatives, a single, mid-range cost is used in this analysis (Table 8).

Included is the cost of application and/or turning, when appropriate. Discounts for live insects were assumed to be $0.08 per bushel for both crops, which is supported by survey information (9), (30). However, further quality losses and price reductions for them are difficult to document. Price reductions were chosen to give a rough estimate of further quality losses and were assumed to be $0.25 per bushel for corn and $0.40 per bushel for wheat (partially based on personal correspondence with Bryan Schurle and Harvey Kiser at Kansas State University and Roger Holtorf with EPA).

The estimate of current total cost of fumigating corn and wheat is $9.5 million, $6.5 million for wheat and $3.2 million for corn (Table 9). Most of this expense is incurred off-farm - approximately $7.1 million. Phosphine accounts for most of the fumigant expenditure at $7.6 million.

The team estimated discounting for live insects and further quality losses for each control practice, crop, and storage position (Table 10). Infested grain treated with any of the fumigants would not be discounted or downgraded. Infested grain treated with protectants would suffer some quality losses because of reduced effectiveness due to excessive heat, moisture, or improper application. Nonchemical controls would result in higher losses than protectants because physical controls such as screening, turning, and aeration are less effective than chemical controls. The highest lossses would occur with no control. The quality losses would be higher for wheat than corn and for on-farm storage than for off-farm. The quality losses caused by removing a fumigant are the average of quality losses for the alternative practices weighted by the proportion of grain previously treated with the fumigant reallocated to each practice. The weighted average is multiplied by the quantity of grain treated with the fumigant in question to estimate the total grain that would be damaged.

1. Impacts of Canceling Phosphine

Canceling phosphine would put greater reliance on chloropicrin, methyl bromide, protectants, and nonchemical controls.

Wheat

Approximately 982 million bushels of wheat are annually treated with phosphine, of which 120 million are on-farm and 862 million are off-farm (Table 6). The total cost of fumigating with phosphine is estimated to be about $5.3 million: $1 million on-farm and $4.3 million off-farm (Table 9).

Of the wheat currently treated with phosphine, only 25 percent of that stored on-farm and 15 percent stored off-farm would be treated with alternative fumigants, if phosphine were removed from the market (Table 11). About 60 percent would be treated with protectants or nonchemical controls, with protectants accounting for a greater portion of the on-farm grain than off-farm grain. Annual treatment costs would increase by $2.4 million: $140,000 on-farm and $2.2 million off-farm (Table 19). A significant proportion of the wheat currently treated with phosphine would go untreated for insects. As a result, large portions of the wheat currently treated with phosphine would be discounted for live insects (9 percent on-farm, 7 percent off-farm) or downgraded (0.9 percent on-farm, 0.4 percent off-farm) (Table 11). The total quality loss is estimated to be about $7.5 million ($1.3 million on-farm and $6.2 million off-farm) (Table 19). As a result, the total cost of losing phosphine for use on wheat would be about $9.9 million ($8.5 million off-farm and $1.4 million on-farm).

Corn

Approximately 442 million bushels of corn are fumigated with phosphine a year (26 million on-farm and 416 million off-farm) (Table 6), at a cost of $2.3 million ($218,000 on-farm and $2.1 million off-farm) (Table 9).

If phosphine were removed form the market, about 40 percent of the corn currently treated on-farm with phosphine would receive other fumigants, 45 percent protectants or nonchemical controls, and 15 percent no insect control (Table 12). About 30 percent of the corn currently treated with phosphine off-farm would receive alternative fumigants, 50 percent protectants or nonchemical controls, and 20 percent no insect control. Insect control costs

would increase $933,000 a year, $19,000 on-farm and $915,000 off-farm (Table 20). Of the corn currently stored on-farm and treated with phosphine, 12.8 percent would be discounted for live insects and 1.3 percent downgraded, if phosphine were banned (Table 12). Of the corn stored and currently treated off-farm, 11.5 percent would be discounted for live insects and 0.4 percent downgraded. The resulting quality loss to corn would be $4.6 million, $344,000 on-farm and $4.2 million off-farm (Table 20). The total loss of banning phosphine would be $5.5 million ($363,000 on-farm and $5.2 million off-farm).

2. Impacts of Canceling Chloropicrin

Removing chloropicrin from the market would put greater reliance on phopshine, methyl bromide, grain protectants, and nonchemical controls.

Wheat

Chloropicrin is used to fumigate about 64 million bushels of wheat (48 million on-farm and 16 million off-farm) (Table 6), only about 7 percent as much wheat as is treated with phosphine. The annual expense of treating with chloropicrin is about $640,000 ($480,000 on-farm and $160,000 off-farm), about one-tenth of the phosphine expenditure (Table 9).

If chloropicrin were removed from the market, about 35 percent of the wheat currently treated with chloropicrin would be treated with phosphine, while 5 percent of such wheat stored off-farm would be treated with methyl bromide (Table 13). About 55 percent of the wheat currently fumigated with methyl bromide would be treated with protectants or nonchemical controls. Annual insect control costs would decrease by $39,000, $32,000 off-farm and $7,000 on-farm (Table 19). About 10 percent of the chloropicrin-treated wheat stored on-farm and 5 percent stored off-farm would be untreated for insects if chloropicrin were banned (Table 13). As a result, about 6.5 percent of the wheat currently treated with chloropicrin and stored on-farm and 3 percent stored off-farm would be discounted for live insects. Less than 1 percent of such wheat in each storage position would be downgraded. The total quality loss which would result from banning chloropicrin on wheat would be about $433,000

($384,000 on-farm and $49,000 off-farm). The total loss to wheat would be about $393,000 ($376,000 on-farm and $17,000 off-farm). The losses caused by banning chloropicrin on wheat would be much less than banning phosphine, because phosphine is applied to a much greater quantity of wheat.

Corn

About 80 million bushels of corn are treated with chloropicrin (60 million on-farm and 20 million off-farm) (Table 6), about 20 percent of the quantity treated with phosphine. The annual expenditure on chloropicrin is about $800,000 ($600,000 on-farm and $200,000 off-farm), one-third of the phosphine expenditure (Table 9).

If chloropicrin were removed from the market, 25 percent of corn once treated with chloropicrin and stored on-farm would be treated with phosphine and 50 percent with grain protectants or nonchemical controls, while 25 percent would receive no insect control practices (Table 14). For chloropicrin-treated corn stored off-farm, 40 percent would be treated with alternative fumigants and 45 percent with protectants or nonchemical controls, while 15 percent would receive no insect controls. Insect control costs would decrease by $160,000 ($99,000 on-farm and $61,000 off-farm) (Table 20). Discounts for live insects would occur on 18.3 percent of the corn currently treated with chloropicrin and stored on-farm and 9 percent of that stored off-farm (Table 14). About 1.8 percent of the corn stored and previously treated on-farm and 0.3 percent stored off-farm would be downgraded. The quality loss caused by banning chloropicrin on corn would be about $1.3 million ($1.1 million on-farm and $159,000 off-farm) (Table 20). The total loss of banning chloropicrin on corn would be about $1.1 million ($1.0 million on-farm and $100,000 off-farm). These losses would be considerably less than those from banning phosphine.

3. Impacts of Canceling Methyl Bromide

Banning methyl bromide would put greater reliance on chloropicrin, phosphine, protectants, and nonchemical controls.

Wheat

About 82 million bushels of wheat are treated with methyl bromide each year (4 million on-farm and 78 million off-farm) (Table 6), a quantity equal to 8 percent of that treated with phosphine. The methyl bromide expenditure is about $321,000 ($12,000 on-farm and $309,000 off-farm), about 6 percent of the phosphine expenditure (Table 9).

All wheat currently treated with methyl bromide would receive an alternative control if methyl bromide were banned. About 45 percent would be treated with an alternative fumigant; chloropicrin would be relied upon more for on-farm stored wheat (Table 15). Insect control costs would increase by $383,000 ($32,000 on-farm and $351,000 off-farm) (Table 19). About 3.5 percent of the wheat stored on-farm and 2.1 percent stored off-farm and currently treated with methyl bromide would be discounted for live insects (Table 15). Less than 1 percent would be downgraded. The total quality loss would be about $174,000 ($17,000 on-farm and $157,000 off-farm) (Table 19). The total annual loss from banning methyl bromide on wheat would be $558,000 ($49,000 on-farm and $508,000 off-farm). This loss would be comparable to that of banning chloropicrin. Each of those fumigants is applied to less than 100 million bushels of wheat, resulting in rather small losses from its ban.

Corn

Approximately 22 million bushels of corn are treated with methyl bromide (1 million on-farm and 21 million off-farm) (Table 6), about 5 percent of the quantity treated with phosphine. The total expenditure on methyl bromide is $90,000 ($3,000 on-farm and $87,000 off-farm) (Table 9).

All the corn currently fumigated with methyl bromide would receive an alternative treatment, if methyl bromide were banned. About 50 percent of corn treated on-farm and 55 percent off-farm would receive treatments of alternative fumigants (Table 16). Insect control costs would increase by $107,000 ($9,000 on-farm and $98,000 off-farm (Table 20). Of the corn treated and stored on-farm, 5.8 percent would be discounted for live insects and 0.6 percent downgraded (Table 16). Of the grain treated and stored off-farm, 2.3 percent

would be discounted for live insects and 0.1 percent downgraded. Quality losses would increase by $50,000 ($7,000 on-farm and $43,000 off-farm) (Table 20). The total loss of banning methyl bromide on corn would be about $157,000 ($16,000 on-farm and $141,000 off-farm), considerably less than banning either phosphine or chloropicrin.

4. Impacts of Canceling All Fumigants

Banning all fumigants puts greater reliance on protectants and nonchemical controls.

Wheat

Approximately 1.1 billion bushels of wheat are fumigated each year (172 million on-farm and 956 million off-farm), about 48 percent of all stored wheat. The total fumigant expenditure is $6.3 million: $1.5 million on-farm and $4.8 million off-farm (Table 9).

If all fumigants were removed from the market, about 15 percent of fumigant-treated wheat stored on-farm and 25 percent stored off-farm would receive no protection against insects (Table 17). Insect control costs would increase by $2.5 million ($57,000 on-farm and $2.4 million off-farm) (Table 19). About 14 percent of the wheat currently fumigated and stored on-farm would be discounted for live insects while 1.5 percent would be downgraded (Table 17). Similarly, 8.1 percent of the off-farm stored wheat that is currently fumigated would be discounted for live insects and 0.5 percent would be downgraded. The total quality loss of removing all wheat fumigants from the market would be about $10.8 million ($2.9 million on-farm and $7.9 million off-farm), resulting in a total loss of $13.3 million ($3.0 million on-farm and $10.3 million off-farm) (Table 19). The total annual loss of banning all fumigants would be about $3.4 million greater than banning phosphine and over $12 million greater than banning either chloropicrin or methyl bromide.

Corn

Approximately 544 million bushels of corn are fumigated each year (87 million on-farm and 457 million off-farm), about 8 percent of all corn stocks.

The total fumigant expenditure on corn is about \$3.2 million (\$822,000 milion on-farm and \$2.4 million off-farm) (Table 9).

If all fumigants were banned, 50 percent of the corn currently fumigated on-farm would instead be treated with protectants and 35 percent with nonchemical controls, while 15 percent would remain untreated (Table 18). About 35 percent of the corn fumigated off-farm would receive protectants, 45 percent nonchemical controls, and 20 percent would go untreated. Insect control costs would increase by \$1.2 million; costs would increase by \$1.3 million off-farm but decrease by \$29,000 on-farm (Table 20). Of the corn currently fumigated and stored on-farm, 21.3 percent would be discounted for live insects and 2.1 percent would be downgraded, if all fumigants were removed from the market (Table 18). Of the off-farm stored grain, 13 percent would be discounted for live insects and 0.5 percent downgraded. The quality loss from banning all fumigants on corn would be about \$7.3 million (\$1.9 million on-farm and \$5.4 million off-farm) (Table 20). The resulting total annual loss would be \$8.6 million (\$1.9 million on-farm and \$6.6 million off-farm). The loss of banning all fumigants on corn would be only marginally greater than banning phosphine.

5. Overall Effect of Canceling Fumigants on Wheat and Corn

The total annual loss of banning all corn and wheat fumigants would be about \$22 million, of which \$18 million (82 percent) would be due to quality losses. Assuming March 1986 commodity prices, the values of the 1982-84 average inventories would be about \$24 billion (\$16 billion for corn and \$8 billion for wheat) assuming that a sudden release of inventories would not drive prices down. If market prices were to fall to 1986 commodity program loan rates, the value would be about \$19 billion (\$13 billion for corn and \$6 billion for wheat). In either case, the loss of removing all fumigants from the market would be on the order of 0.1 percent of the value of grain inventories. The loss of banning phosphine would be \$15 million, about two-thirds of losing all fumigants. The losses from banning chloropicrin or methyl bromide would be much less: \$1.5 million and \$700,000, respectively.

While these losses are small, they would be concentrated on those who would attempt to control infestations but suffer losses because fumigants were not available. The average loss to currently fumigated grain would be about $0.016 per bushel for corn and $0.011 for wheat if all fumigants were banned. For those suffering a quality loss, the average loss would be $0.09 per bushel for corn and $0.10 for wheat. Those who did nothing to control insects and were unlucky enough to have quality losses which require deductions beyond discounts for live insects could suffer much greater losses. It seems possible that many who would have fummigated, but did nothing to control insects after the loss of fumigants, would decide to use grain protectants or other insect control practices. They might do so because the potential magnitude of quality losses is considerably greater than insect control costs. In addition, price discounts for live insects could increase if fumigants were removed from the market because quantities of infested grain would increase.

Table 8. Costs of fumigants and alternatives

Control	Onfarm	Off-farm
	Dollars per 1,000 bushels	
Phosphine	8.50	5.00
Chloropicrin	10.00	10.00
Methyl bromide	3.00	4.00
Grain protectants 1/	13.00	13.00
Nonchemical controls 2/	7.50	7.50

1/ Includes liquid and dust formulations of malathion, chlorpyrifos-methyl (registered for wheat only), and pirimphos-methyl (for export only).

2/ Includes turning, aeration, aspiration, and screening at a cost of \$2-\$5 per 1,000 bushels, diatomaceous earth at \$30 per 1,000 bushels, and modified atmospheres at \$5-\$40 per 1,000 bushels.

Table 9. Current cost of fumigating corn and wheat

Storage position/fumigant	Wheat	Corn	Total
		Dollars	
Onfarm			
Phosphine	1,018,300	218,450	1,236,750
Chloropicrin	480,000	600,000	1,080,000
Methyl bromide	12,180	3,420	15,600
All fumigants	1,510,480	821,870	2,332,350
Off-farm			
Phosphine	4,312,000	2,079,000	6,391,000
Chloropicrin	160,000	200,000	360,000
Methyl bromide	308,560	86,640	395,200
All fumigants	4,780,560	2,365,640	7,146,200
Total			
Phosphine	5,330,300	2,297,450	7,627,750
Chloropicrin	640,000	800,000	1,440,000
Methyl bromide	320,740	90,060	410,800
All fumigants	6,291,040	3,187,510	9,478,550

Table 10. Discounting and downgrading

Crop/ Control	Onfarm Discounted	Onfarm Downgraded	Off-farm Discounted	Off-farm Downgraded
	Percent			
Corn				
Phosphine	0.0	0.0	0.0	0.0
Chloropicrin	0.0	0.0	0.0	0.0
Methyl bromide	0.0	0.0	0.0	0.0
Grain protectants	10.0	1.0	5.0	0.0
Nonchemical	25.0	2.5	5.0	0.5
No control	50.0	5.0	45.0	1.5
Wheat				
Phosphine	0.0	0.0	0.0	0.0
Chloropicrin	0.0	0.0	0.0	0.0
Methyl bromide	0.0	0.0	0.0	0.0
Grain protectants	5.0	0.5	3.0	0.0
Nonchemical	20.0	2.0	5.0	0.5
No control	30.0	3.5	20.0	1.0

Table 11. Control changes and quality losses caused by losing phosphine on wheat

Reallocation of phosphine-treated wheat to alternative practices	Onfarm		Off-farm	
	Percent	Bushels (1,000's)	Percent	Bushels (1,000's)
Chloropicrin	20	23,960	5	43,120
Methyl bromide	5	5,990	10	86,240
Grain protectants	55	65,890	40	344,960
Nonchemical controls	5	5,990	20	172,480
No control	15	17,970	25	215,600
Totals	100	119,800	100	862,400
Resulting quality losses to phosphine-treated wheat:				
Quantity discounted	9.0	10,782	7.2	62,093
Quantity downgraded	0.9	1,078	0.4	3,018

Table 12. Control changes and quality losses caused by losing phosphine on corn

Reallocation of phosphine-treated corn to alternative practices	Onfarm		Off-farm	
	Percent	Bushels (1,000's)	Percent	Bushels (1,000's)
Chloropicrin	35	8,995	10	41,580
Methyl bromide	5	1,285	20	83,160
Grain protectants	40	10,280	30	124,740
Nonchemical controls	5	1,285	20	83,160
No control	15	3,855	20	83,160
Totals	100	25,700	100	415,800
Resulting quality losses to phosphine-treated corn:				
Quantity discounted	12.8	3,277	11.5	47,817
Quantity downgraded	1.3	328	0.4	1,663

Table 13. Control changes and quality losses caused by losing chloropicrin on wheat

Reallocation of chloropicrin-treated wheat to alternative practices	Onfarm		Off-farm	
	Percent	Bushels (1,000's)	Percent	Bushels (1,000's)
Phosphine	35	16,800	35	5,600
Methyl bromide	0	0	5	800
Grain protectants	50	24,000	35	5,600
Nonchemical controls	5	2,400	20	3,200
No control	10	4,800	5	800
Totals	100	48,000	100	16,000
Resulting quality losses to chloropicrin-treated wheat:				
Quantity discounted	6.5	3,120	3.1	488
Quantity downgraded	0.7	336	0.2	24

Table 14. Control changes and quality losses caused by losing chloropicrin on corn

Reallocation of chloropicrin-treated corn to alternative practices	Onfarm		Off-farm	
	Percent	Bushels (1,000's)	Percent	Bushels (1,000's)
Phosphine	25	15,000	35	7,000
Methyl bromide	0	0	5	1,000
Grain protectants	45	27,000	30	6,000
Nonchemical controls	5	3,000	15	3,000
No control	25	15,000	15	3,000
Totals	100	60,000	100	20,000
Resulting quality losses to chloropicrin-treated corn:				
Quantity discounted	18.3	10,950	9.0	1,800
Quantity downgraded	1.8	1,095	0.3	60

Table 15. Control changes and quality losses caused by losing methyl bromide on wheat

Reallocation of methyl bromide-treated wheat to alternative practices	Onfarm		Off-farm	
	Percent	Bushels (1,000's)	Percent	Bushels (1,000's)
Phosphine	30	1,218	40	30,856
Chloropicrin	15	609	5	3,857
Grain protectants	50	2,030	35	26,999
Nonchemical controls	5	203	20	15,428
No control	0	0	0	0
Totals	100	4,060	100	77,140
Resulting quality losses to methyl bromide-treated wheat:				
Quantity discounted	3.5	142	2.1	1,581
Quantity downgraded	0.4	14	0.1	77

Table 16. Control changes and quality losses caused by losing methyl bromide on corn

Reallocation of methyl bromide-treated corn to alternative practices	Onfarm		Off-farm	
	Percent	Bushels (1,000's)	Percent	Bushels (1,000's)
Phosphine	25	285	40	8,664
Chloropicrin	25	285	15	3,249
Grain protectants	45	513	30	6,498
Nonchemical controls	5	57	15	3,249
No control	0	0	0	0
Totals	100	1,140	100	21,660
Resulting quality losses to methyl bromide-treated corn:				
Quantity discounted	5.8	66	2.3	487
Quantity downgraded	0.6	7	0.1	16

Table 17. Control changes and quality losses caused by losing all fumigants on wheat

Reallocation of fumigated wheat to alternative practices	Onfarm		Off-farm	
	Percent	Bushels (1,000's)	Percent	Bushels (1,000's)
Grain protectants	50	85,930	35	334,439
Nonchemical controls	35	60,151	40	382,216
No control	15	25,779	25	238,885
Totals	100	171,860	100	955,540
Resulting quality losses to fumigated wheat:				
Quantity discounted	14.0	24,060	8.1	76,921
Quantity downgraded	1.5	2,535	0.5	4,300

Table 18. Control changes and quality losses caused by losing all fumigants on corn

Reallocation of fumigated corn to alternative practices	Onfarm		Off-farm	
	Percent	Bushels (1,000's)	Percent	Bushels (1,000's)
Grain protectants	50	43,420	35	160,111
Nonchemical controls	35	30,394	45	205,857
No control	15	13,026	20	91,492
Totals	100	86,840	100	457,460
Resulting quality losses to fumigated corn:				
Quantity discounted	21.3	18,454	13.0	59,470
Quantity downgraded	2.1	1,845	0.5	2,402

Table 19. Economic effects of losing fumigants used on wheat

Fumigant/Effect	Onfarm	Off-farm	Total
		Dollars	
Phosphine			
Current Cost	1,018,300	4,312,000	5,330,300
Projected cost	1,159,065	6,554,240	7,713,305
Cost increase	140,765	2,242,240	2,383,005
Discounting loss	862,560	4,967,424	5,829,984
Downgrading loss	431,280	1,207,360	1,638,640
Total quality loss	1,293,840	6,174,784	7,468,624
Total loss	1,434,605	8,417,024	9,851,629
Chloropicrin			
Current Cost	480,000	160,000	640,000
Projected cost	472,800	128,000	600,800
Cost increase	-7,200	-32,000	-39,200
Discounting loss	249,600	39,040	288,640
Downgrading loss	134,400	9,600	144,000
Total quality loss	384,000	48,640	432,640
Total loss	376,800	16,640	393,440
Methyl Bromide			
Current Cost	12,180	308,560	320,740
Projected cost	44,356	659,547	703,903
Cost increase	32,176	350,987	383,163
Discounting loss	11,368	126,510	137,878
Downgrading loss	5,684	30,856	36,540
Total quality loss	17,052	157,366	174,418
Total loss	49,228	508,353	557,580
All fumigants			
Current Cost	1,510,480	4,780,560	6,291,040
Projected cost	1,568,223	7,214,327	8,782,550
Cost increase	57,743	2,433,767	2,491,510
Discounting loss	1,924,832	6,153,678	8,078,510
Downgrading loss	1,013,974	1,719,972	2,733,946
Total quality loss	2,938,806	7,873,650	10,812,456
Total loss	2,996,549	10,307,417	13,303,965

Table 20. Economic effects of losing fumigants used on corn

Fumigant/Effect	Onfarm	Off-farm	Total
		Dollars	
Phosphine			
Current Cost	218,450	2,079,000	2,297,450
Projected cost	237,083	2,993,760	3,230,843
Cost increase	18,633	914,760	933,393
Discounting loss	262,140	3,825,360	4,087,500
Downgrading loss	81,919	415,800	497,719
Total quality loss	344,059	4,241,160	4,585,219
Total loss	362,691	5,155,920	5,518,611
Chloropicrin			
Current Cost	600,000	200,000	800,000
Projected cost	501,000	139,500	640,500
Cost increase	-99,000	-60,500	-159,500
Discounting loss	876,000	144,000	1,020,000
Downgrading loss	273,750	15,000	288,750
Total quality loss	1,149,750	159,000	1,308,750
Total loss	1,050,750	98,500	1,149,250
Methyl Bromide			
Current Cost	3,420	86,640	90,060
Projected cost	12,369	184,652	197,021
Cost increase	8,949	98,012	106,961
Discounting loss	5,244	38,988	44,232
Downgrading loss	1,639	4,061	5,700
Total quality loss	6,883	43,049	49,932
Total loss	15,832	141,061	156,893
All fumigants			
Current Cost	821,870	2,365,640	3,187,510
Projected cost	792,415	3,625,371	4,417,786
Cost increase	-29,455	1,259,731	1,230,276
Discounting loss	1,476,280	4,757,584	6,233,864
Downgrading loss	461,338	600,416	1,061,754
Total quality loss	1,937,618	5,358,000	7,295,618
Total loss	1,908,163	6,617,731	8,525,893

B. Peanuts

1. Peanut Storage and Pesticide Use

Nearly all peanuts are stored off-farm. The breakdown by farmer stock (inshell), roasting stock (inshell and in cold storage), and shelled peanuts from 1982 to 1985 is presented in Table 4. The 1982-84 averages are 832,000 tons of Jan. 1 farmer stock, 294,000 tons Jan. 1 shell stock and 1.9 million tons of production (Tables 4 and 21). Peanuts go into storage at harvest and almost all are shelled by the following summer. Before shelling, some stored peanuts are fumigated with aluminum phosphide or treated with nonfumigant protectants, such as malathion, to control insects. Some shelled peanuts are fumigated with methyl bromide for the same purpose. After shelling, most peanuts are eventually put into cold storage when they are no longer treated with pesticides. The cost of alternative practices are presented in Table 22.

The team estimated that approximately 20 percent of the Jan. 1 farmer stock (inshell peanuts) is fumigated with aluminum phosphide which produces phosphine gas (Table 7). No significant amount of magnesium phosphide is used. Assuming the 1982-84 average, the use of phosphine is approximately 21,000 kilograms per year. The team also estimated that 30 percent of total production is fumigated with methyl bromide for a total of about 840,000 pounds using the 1982-84 average. In addition, about 65 percent of total production is treated with protectants, primarily malathion, for a total of about 50 thousand pounds per year. The total cost of treating with these materials is approximately $1.4 million per year.

Quality losses are assumed to be $0.18 per bushel if peanuts are downgraded to oilstock. If peanuts are rejected at purchase due to live insects, the loss is assumed to be $.05 per bushel due to return, screening, and cleaning.

2. Impacts of Canceling Fumigants

Phosphine

Canceling aluminum and magnesium phosphide would result in greater reliance on methyl bromide, grain protectants, cold storage, and DDVP pest strips, while quality losses would increase (Table 23). The team estimated that approximately 10 percent of Jan. 1 farmer stocks would be treated with methyl bromide (50 percent of phosphine treated peanuts) after shelling. Storages treated with methyl bromide would require sealing to prevent fumigant escape, at a cost of about $.43 per 1,000 pounds of peanuts. Treatments with protectants would increase to approximately 90 percent of total production from about 65 percent. About 50 percent of the Jan. 1 stock of shelled peanuts would require additional DDVP pest strips. About 2 percent of total production (10 percent of phosphine-treated peanuts) would be shelled and put into cold storage an average of 4.5 months earlier than normal, at a cost of $2.20 per 1,000 pounds per month. Cold storage facilities could be in short supply, making it difficult to increase the time peanuts are in cold storage. Estimated insect control costs would increase to about $2.7 million from the current $1.4 million (Table 26).

The team estimated that an additional 6 percent of Jan. 1 farmer stock would be downgraded from No. 1 edible stock to oilstock, at a discount of $0.18 cents per pound (Table 23). The total loss to downgrading would be about $17.9 million (Table 26). The total loss of losing phosphides would be about $19.3 million, the major portion of which would be due to downgrading.

Methyl Bromide

Canceling methylbromide would force greater reliance on aluminum phosphide, cold storage, and DDVP pest strips (Table 24). The team estimated that 26 percent of the Jan. 1 farmer stocks would be treated with aluminum phosphide (85 percent of methyl bromide treated peanuts). About 3 percent of total production (10 percent of methyl bromide treated peanuts) would go into cold storage an average of 4.5 months earlier than usual. Also, DDVP use would increase on about 5 percent of production (15 percent of methyl bromide treated

peanuts). There would be no significant change in the use of protectants which would remain at about 65 percent of annual production. The team predicted that there would be no significant change in the quality of stored peanuts, so the total loss would be the increase in treatment costs. Insect control costs would increase to about $2 million for an increase of about $600,000 (Table 26). The total loss to storers of banning phosphides would be about $18.7 million greater than banning methyl bromide.

All Fumigants

Canceling both the phosphides and methyl bromide would cause increased reliance on protectants, earlier cold storage, and DDVP pest strips, while quality losses would be greater than cancelling only the phosphides (Table 25). The team estimated that treatments with protectants would increase to 90 percent of total production of peanuts from 65 percent. Additional DDVP pest strips would be used on 50 percent of Jan. 1 farmer stock and 10 percent of Jan. 1 shelled stock. Also, 3 percent of total production would be shelled and put into cold storage an average of 4.5 months earlier than usual. Insect control costs would increase to about $2.4 million per year from about $1.4 million -- an increase of about $970,000 per year (Table 26).

Quality losses would increase substantially. The team estimated that about 6 percent of Jan. 1 farmer stock would be downgraded from No. 1 edible stock to oil stock, at a discount of $0.18 per pound (Table 25). In addition, 5 percent of total production might be rejected by purchasers due to insect infestation. Rejected peanuts would be sent back to the shipper for screening and cleaning, at an estimated cost of $0.05 per pound. The total loss would be about $28 million of which $18 million would be due to downgrading to oilstock and $9.3 million due to rejections for live insects (Table 26).

The total loss of banning all fumigants would be about $9 million per year greater than banning only aluminum phosphide and about $27.5 million greater than banning only methyl bromide. Assuming a peanut price of $0.24 per pound, the value of Jan. 1 peanut inventories is about $602 million. The loss

of banning all fumigants for use on peanuts would be about 5 percent of the value of total inventories.

3. Longer-Term Impacts

The increased downgrading of edible stocks to oilstocks, if the phosphides or all fumigants are banned, would increase oilstocks by 20 to 25 percent. This would likely depress oilstock prices and increase the price spread between the two grades. If so, the prices of edible grade peanuts would increase and oilstocks decrease. These price changes would affect both producers and consumers. The sellers of edible peanuts will be better off due to higher prices, while the sellers of oilstocks will be worse off. How this affects individual storers or producers will depend on the amount of each grade they sell. The purchasers of products of edible peanuts will be worse off due to higher prices and smaller supplies but the purchasers of oil products will be better off due to lower prices and larger supplies. How the downgrading affects the value of peanut production, producer profits, and consumer welfare will be a function of the price elasticities of demand for edible peanuts and oilstocks. These effects will not be examined in greater detail. Banning methyl bromide will have little effect on the price spread because no significant downgrading would occur.

All three fumigant scenarios increase the costs of supplying peanuts to the retail market. The control of storage insects would increase under all three scenarios, while the costs of transportinig, cleaning, and screening peanuts rejected due to the presence of live insects would increase if all fumigants were banned. Ultimately, one would expect the total production of peanuts in the U.S. to decrease and prices to increase. The smallest impacts would occur if methyl bromide only were banned, while the largest would occur if all fumigants used for peanuts were banned. Consumers would certainly be worse off due to higher prices and smaller supplies of peanut products. Whether producers and storers would be better or worse off would depend on whether revenues from peanuts increase more or less than the costs (including insect

control costs and losses due to downgrading and rejection due to presence of live insects), which in turn depends on the price elasticities of demand and supply.

Table 21. Peanut production

Year	Quantity Produced
	1,000 pounds
1982	3,440,255
1983	3,295,530
1984	4,405,745
1985	4,256,300
Averages	
1982-84	3,713,843
1983-85	3,985,858

Source: Crop production, SRS, USDA.

Table 22. Pest control costs for stored peanuts

Control practice	Cost per ton	Cost per 1,000 lb
	Dollars	
Phosphine	1.1210	0.5605
Methyl Bromide	1.1210	0.5605
Malathion(grain protectant)	0.4920	0.2460
Cold Storage(monthly basis)	4.4000	2.2000
DDVP	1.0000	0.5000

Table 23. Change in control practices and quality losses resulting from banning phosphine for stored peanuts

Alternative controls	Quantity of peanuts		
	Percent of source	Source 1/	Pounds (1,000's)
Methyl Bromide	10	A	166,345
Seal storages	10	A	166,345
Grain protectants	90	C	3,342,459
Cold Storage(4 1/2 months)	2	C	74,277
DDVP	50	B	294,247
Quality loss:			
Downgraded	6	A	99,807

1/ A = Jan. 1 farmer stock
B = Jan. 1 shelled stock
C = Annual production

Table 24. Change in control practices and quality losses resulting from banning methyl bromide for stored peanuts

Alternative controls	Quantity of peanuts		
	Percent of source	Source 1/	Pounds (1,000's)
Phosphine	26	A	242,415
Grain protectants	65	C	593,843
Cold Storage(4 1/2 months)	3	C	1,103,011
DDVP	5	B	92,846
Quality loss:			
Downgraded	0	A	0

1/ A = Jan. 1 farmer stock
B = Jan. 1 shelled stock
C = Annual production

Table 25. Change in control practices and quality losses resulting from banning all fumigants for stored peanuts

Alternative controls	Quantity of peanuts		
	Percent of source	Source 1/	Pounds (1,000's)
Grain protectants	90	C	822,245
Cold Storage(4 1/2 months)	3	C	1,103,011
DDVP	50	A	415,863
DDVP	10	B	29,425
Quality loss:			
Downgraded	5	A	99,807
Rejected	5	C	185,692

1/ A = Jan. 1 farmer stock
B = Jan. 1 shelled stock
C = Annual production

Table 26. Economic effects of losing fumigants used on peanuts

Fumigant/ effect	Dollars
Phosphine	
Current cost	1,404,799
Projected cost	2,690,887
Cost change	1,286,088
Downgraded peanuts	17,965,271
Total loss	19,251,359
Methyl bromide	
Current cost	1,404,799
Projected cost	2,032,116
Cost change	627,317
Downgraded peanuts	0
Total loss	627,317
All fumigants	
Current cost	1,404,799
Projected cost	2,370,544
Cost change	965,745
Downgraded peanuts	17,965,271
Rejected peanuts	9,284,608
Total quality loss	27,249,878
Total loss	28,215,623

GRAIN RELATED FUMIGANT USES

Milling and Processing Industry

General grain stock fumigations by the milling and processing industry are included in the off-farm storage positions previously discussed. The control of insect pests in milling and processing equipment presents many problems not encountered in bulk grain storages. There are many recesses and cavities in machinery where milled products tend to remain static during normal operations. Insects are able to find these sites, deposit eggs in the products and multiply. If undetected, the infestations will eventually find their way into the finished product, passing through the processing equipment.

Flour mill sanitation programs were described by Smith (25) in 1981 as composed of three elements: 1) a housekeeping program that includes standardized procedures to clean equipment and plant areas, 2) judicious use of pesticides in conformance with applicable Federal requirements, and 3) a prevention inspection program on incoming raw materials, mill equipment, the facility itself, and outbound transportation equipment. However, of the fumigants identified by Smith (25) as routinely used in spot treatments of mill equipment (carbon tetrachloride, ethylene dibromide, ethylene dichloride, methyl bromide), only methyl bromide remains. Magnesium phosphide formulated in cloth-covered plates or strips of plates sealed in plastic envelopes is now being marketed as a spot treatment for milling, processing, and grain handling equipment. This formula releases the same phosphine gas as the aluminum phosphide material, only more rapidly.

Opinions differ among plant sanitarians as to the impact of loss of fumigant materials on pest management programs in the milling and processing industry. Many believe that no reliable alternatives to spot fumigants are available to the milling industry and even if materials for general fumigation are retained, they question whether such treatments would be "efficacious" in the control of flour mill insects hidden away in the recesses of milling machinery. Others see the actions on fumigants as a rationale for broadening control programs into a more integrated pest management strategy composed of

both non-chemical and chemical pest control elements. Most agree, however, that the loss of ethylene dibromide-methyl bromide combinations for spot treatment created many short-term problems, especially at older plant locations where improved cleaning of pest harborages was difficult to achieve and where years of dependence on low cost spot fumigations had discouraged development of more balanced control programs.

In the long term, public concerns with pesticide residues and industry sensitivity about product "contamination" may loosen the cost constraints on sanitation programs and permit the development of alternative control strategies such as plant heat-ups (11) as well as revised application techniques to improve the efficiency of those chemicals used.

In-Transit Shipboard Fumigation

The Unites States Department of Agriculture's (USDA) Agricultural Research Service (ARS) and the Federal Grain Inspection Station (FGIS) have developed and implemented an in-transit shipboard fumigation program that is a safe, effective, and economical means for controlling insect infestation in U.S. export grain.

Prior to 1976, when grain being loaded aboard a ship was found to be infested in accordance with the "Official United States Standards for Grain," the shipper had three options: 1) To accept a grade certificate indicating the grain was infested; 2) off-load or remove the infested grain from the ship; or 3) stop loading and fumigate the infested grain aboard the ship for at least 12 hours with a subsequent examination of the grain to ensure that the insects have been killed.

The first option of receiving a certificate indicating the grain is infested was rarely, if ever, chosen as buyers do not contract for infested grain. The second option of removing the infested grain from the vessel is time consuming and costly. U.S. export facilities are designed only to load grain. Consequently, the removal of grain from the ship usually requires the use of a

floating crane and barge which must be transported to the site. The third option of fumigating the insect infested grain aboard the ship causes considerable delays in loading, particularly when the other holds of the vessel are completely loaded or are out of position for loading during the 12-hour fumigation. However, the major objections to this latter option were: 1) the potential safety hazard to grain inspectors reentering the hold after the fumigation to determine efficacy; 2) inadequate fumigation schedule which permitted a minimum fumigant exposure time of 12 hours rather than the several days necessary to achieve a complete fumigation; and 3) fumigant dosage based on the amount of grain in the hold rather than the cubic capacity of the hold.

In an effort to develop a safer, more effective and economical means for controlling insect infestation in U.S. export grain, ARS with the support of FGIS began a research program in 1975 to evaluate in-transit shipboard fumigation as a potential solution. This program included several features: 1) Loading of grain could continue when insect infestation was detected; 2) fumigation would take place after the grain was completely loaded and the holds properly sealed; and 3) grain inspectors would not need to reenter the fumigated holds to determine efficacy.

Based on the research conducted by ARS on those 13 ships, FGIS has issued instructions, beginning in 1976, to implement the in-transit shipboard fumigation program. The instructions have been revised several times based on ARS research and focus on ensuring the use of safe and effective fumigation procedures. (GR 918-6, Auxiliary 19, Revision 2, Shiphold Fumigation, dated September 12, 1977, and FGIS Instruction 919-1, In-Transit Fumigation of Grain Loaded Aboard Tanker-Type Vessels, dated April 21, 1982.)

The data generated by this research program has been the basis for the United States to successfully petition a revision to the United Nation's International Maritime Organization's, Maritime Safety Committee's (MSC) Circular No. 298 Rev. entitled "Recommendations on the Safe Use of Pesticides in Ships" to include in-transit shipboard fumigation of grain. The new revision was issued as supplement 267, 81.08.E, to MSC Circular No. 298.

Since 1976, more than 4,500 ships loaded with grain have sailed from U.S. ports with one or more holds under fumigation with a proven record of safety and efficacy. Moreover, several countries, such as Chile, People's Republic of China, Peru, and the USSR have required some or all of their grain imports be fumigated in transit. Research is being continued to seek improvements upon the current technology and to develop methodology to extend the in-transit shipboard fumigation procedure to other types of ships and commodities.

RESEARCH NEEDS

Short term research projects designed to develop cost relevant pest management techniques that can be used to reduce post harvest dependence on chemical fumigation in both farm and commercial storages are needed immediately. Large carry overs of grain stocks will be present in the market over the next several years. A significant amount of this grain will be placed in temporary storage structures such as plastic covered bunkers. The U.S. experience with this type of storage is very limited and its impact on insect development, pesticide efficacy and treatment procedures should be investigated.

Research directed at reducing losses in bulk stored grain should be augmented with a systematic program to regularly monitor insect populations and control practices in the grain marketing system. The program should include: (1) screening for insect resistance to the available fumigants and grain protectants in use; (2) identification of insect population trends associated with the loss of fumigant materials, the adoption of alternate pest management techniques, and changes in storage and marketing practices; and (3) an ongoing assessment of current control practices in terms of the types of chemical and nonchemical methods used, the volume of grain treated, costs and availability of treatments, and efficacy.

SUMMARY

The fumigation of wheat, corn, and peanuts is a specialized form of remedial insect control in bulk stored commodities that presently involves only three approved fumigant compounds: aluminum phosphide, methyl bromide, and chloropicrin. No other type of pesticide treatment can reach infestation deep within the commodity bulk and no other chemical or nonchemical method of disinfestation offers the same combination of adaptability, simple application, low cost, and comparatively fast action as do fumigants.

Fumigant use in wheat and corn has evolved over the past 50 years from a market dominated up to the early 1960's by liquid fumigant mixtures of carbon tetrachloride, carbon disulfide, ethylene dichloride, and ethylene dibromide to the present time in which aluminum phosphide fumigants account for 85% of the fumigated grain, chloropicrin 9% and methyl bromide 6%. At their peak use, the annual liquid fumigant market was sufficient to treat 25% of the grain handled through the U.S. marketing system. Today, the combined market of aluminum phosphide, methyl bromide and chloropicrin treats only 15% of the approximate 10 billion bushels produced and handled annually.

Fumigant use in peanuts is characterized by reliance on aluminum phosphide materials for treating in-shell peanuts in warehouses and on methyl bromide for shelled peanuts in transportation containers. Liquid fumigant mixtures and chloropicrin have not been used to any extent on either in-shell or shelled peanuts.

State extension and pesticide regulatory officials consider fumigants as necessary pest management tools whose loss would adversely affect the quailty of grain in storage. Most believe that the loss of individual fumigants would increase the use of grain protectants and nonchemical control, but do not believe that non-fumigant control stategies alone would be sufficient to prevent insect infestations if all fumigant materials were discontinued.

The biological and economic consequences of insect infestations in grain are established by both government and grain industry regulations, guidelines, and marketing policies that interact to set the degree of market penalty applied for insect contamination and damages. The nature of the market penalty also influences the pest management strategy used to address the insect problem. Market discounting of grain for the presence of insects is a common practice especially at the initial point of delivery from farm storage to country elevator. Also, the level of insect activity present in grain being prepared for transhippment between other market points may cause the grain to be cleaned, reblended, or fumigated before it will pass insect requirements imposed by the buyer or insect tolerances permitted under official state or federal grain inspection guidelines. In the short term, fumigation remains the only practical solution to the immediate problem of reducing insect activity already present in grain moving through the market system. In the long term, dependence on chemical fumigants could be reduced by a national reemphasis on the use of preventive measures (grain protectants, aeration cooling, prebin cleaning and treatment), particularly at the farm and country elevator levels. The shifting of primary pest management strategies to preventive rather than remedial procedures would reduce the overall frequency and severity of insect populations entering the grain market system, thereby limiting the situations in which chemical fumigations are necessary.

Recommendations are under consideration that will gradually lower insect tolerances and redefine the term "weevily" to more accurately reflect true levels of insect infestation when grain is graded. These changes will likely increase pressure throughout the marketing system to expand and improve control of insects in grain. Because pesticides continue to be the principal component of pest management practices in stored grain, their overall use will be increased.

The economic loss of removing all stored corn and wheat fumigants from the market, under current use patterns, would be about $18 million annually, of which $15 million would be due to quality losses. This loss is about 0.1 percent of the value of grain inventories. The economic loss of removing phosphine for wheat and corn would be about $15 million but would be much less for losing chloropicrin, $1.5 million, or methyl bromide, $700,000. The total loss of removing all stored peanut fumigants from the market would be about $28 million, primarily due to quality losses. This loss approximates 5 percent of the value of January 1 peanut inventories. The economic loss from removing phosphine for stored peanuts would be $19 million and from methyl bromide about $600,000. While the aggregate losses for wheat and corn are not great, farmers with heavy insect infestations in their grain can suffer large financial losses without remedial treatments. Financial losses could increase if standards for insect infestations are tightened.

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APPENDICES

A. Reply from Stauffer Chemical Company to Special Data Claim Notice for CS_2 and CCl_4.

B. Milling Industry's Position on the Use of Liquid Grain Fumigants.

C. U.S. Fumigant Suppliers Cooperating in Fumigant Assessment.

D. Fumigant Assessment Worksheet Used at the Fumigation and Grain Protectant Training Conference, Corpus Christi, Texas, February 1985.

Stauffer Chemical Company
1828 L Street, N.W./Washington, D.C. 20036/Telephone (202) 331-1627

July 9, 1984

Director, Registration Division (TS-767)
Office of Pesticide Programs
U. S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

D R A F T

Attn: Geraldine Werdig - Carbon Disulfide (Special)
- Carbon Tetrachloride (Special)

Subject: Special Data Call-In Notices for Carbon Disulfide (CS_2) and Carbon Tetrachloride (CCl_4)

Dear Ms. Werdig:

We have received the Agency's Data Call-In Notices for carbon disulfide (CS_2) and carbon tetrachloride (CCl_4). Stauffer products affected by these notices are:

EPA REGISTRATION NO.	PRODUCT
476-1	Carbon Disulfide
476-537	"80-20" Grain Fumigant
476-1112	F.I.A. "80-20" Grain Fumigant
476-1113	F.I.A. "80-20" Grain Fumigant with SO_2

We have analyzed the costs in developing the data to satisfy these requirements and find the costs far exceed the total profit that can reasonably be expected from these products for the next five to ten years.

In view of this, Stauffer Chemical Company respectfully proposes that, in order to adequately prepare for availability of these products for agricultural users especially in light of recent removal of other major grain fumigant products, and to ensure an adequate interval for customers' inventory disposition, that the Agency consider allowing production of grain fumigants products containing the subject active ingredients (including SO_2) until December 31, 1984 and subsequent marketing of these products until December 31, 1986.

In conjunction with this request, Stauffer Chemical Company hereby commits to formally requesting voluntary cancellation of our grain fumigant products (see Attachment B1 and B2) effective as of December 31, 1984.

We believe that granting our request will enable Stauffer Chemical Company, it's distributors, customers and the agricultural community to effectively service the existing grain fumigant market. As proposed, Stauffer Chemical Company

Ms. Geraldine Werdig
Page 2
July 9, 1984

will stop producing products for reformulation/repackaging as of December 31, 1984, with the understanding that we, as well as our customers have until December 31, 1986 to duly dispose of inventory existing as of the above date.

Thank you in advance for your comments and cooperation.

Sincerely yours,

JACK J. WISE
Manager
Regulatory Relations

JJW/bbw

MILLERS'
NATIONAL
FEDERATION

600 Maryland Avenue, S.W., Suite 305 West Wing • Washington, D.C. 20024 • 202-484-2200

March 1, 1985

Mr. Winand K. Hock
Coordinator
Pesticide Chemicals
419 Agricultural Administration Bldg.
Pennsylvania State University
University Park, PA 16802

Subject: MILLING INDUSTRY'S POSITION ON THE USE OF LIQUID GRAIN FUMIGANTS

Dear Mr. Hock:

The Millers' National Federation is the national trade association of the wheat flour milling industry. Its members operate over 80% of the U.S. milling capacity. As wheat flour manufacturers, we are interested in the proper storage and handling of wheat to prevent insect infestation. In addition, we are very interested in the continued safe application of pesticides.

The consumers of wheat based foods are increasingly concerned with the safety of products containing pesticide residues. Media reaction surrounding the regulation of ethylene dibromide seemed to heighten these concerns. Information on existing pesticide residue levels in wheat flour does not suggest a health risk to consumers. Nevertheless, milling companies are working to reduce and, when possible, eliminate residues from final products.

The Environmental Protection Agency (EPA) has taken action which impacts on the use of liquid fumigants on wheat. As of January 1, 1985 it is no longer legal to manufacture liquid grain fumigants containing carbon tetrachloride, carbon bisulfide or ethylene dichloride. A Federal Register notice explaining this action is expected in March or April. The cancellation of the registrations for these fumigants will allow one year (to December 31, 1985) for the phasing out of existing supplies. We ask that you, as an official responsible for pesticide applicator training, communicate to users and your extension personnel the regulatory status of these fumigants. In addition, please let it be known that the U.S. wheat flour milling industry would prefer that use of liquid fumigants on wheat be voluntarily stopped immediately.

Wheat fumigation is necessary to limit losses to pests and preserve quality. If non-chemical grain quality management techniques or the use of grain protectants have not been successful in preventing insect infestation in wheat which is intended for human consumption, we would suggest the use of phosphine-based fumigants.

We will be working on the federal level to ensure adequate funding for state training programs. These training programs are a valuable tool for encouraging the continued safe use of chemicals throughout the food chain. If we have a member of our organization in your state, we may be able to assist in planning or in providing technical information or speakers for your pesticide certification training programs. If we may be of any assistance, please let me know.

One final request -- please provide me copies or a list of titles of any publications on grain storage and fumigation which have been prepared or circulated through your state extension service. Your prompt consideration of these requests is greatly appreciated.

Sincerely,

Tom Klevay
Director of Regulatory Affairs

TK:dmc

cc: Mr. Gerard J. Florentine

United States Department of Agriculture

Agricultural Research Service

North Central Region
U.S. Grain Marketing Research Laboratory

1515 College Avenue
Manhattan, Kansas
66502

August 16, 1985

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This letter confirms my phone call inviting you to participate in a meeting of the U.S. fumigant suppliers to be held from 1:00 to 5:00 p.m. on the afternoon of August 27th and from 8:00 a.m. to noon the following day, August 28th. The meeting will be held in the conference room of the Standardization Division of the Federal Grain Inspection Service which is located in Building #221 at Richards Gebaur Air Force Base just southeast of Kansas City, Missouri. A suggested route for reaching this location is to travel south on Highway 71 to Grandview, Missouri, turn right (west) at the 155th street exit (marked by a Richards Gebaur AB sign) and proceed to the first flashing caution light after entering the base. Turn left (south) at the light and the Standardization office is the first large building on the left (east) side of the street.

Your cooperation in the preparation of USDA's National Fumigant Assessment Report will ensure that the role of fumigants in pest management programs is accurately portrayed and that your views in support of this important group of pesticide chemicals are clearly expressed.

The purpose of this assessment is to provide the Department of Agriculture with a national overview of the impact of the loss of fumigants on agriculture should further regulatory action be taken to cancel these pesticide registrations. The assessment will address fumigant use in four principal areas: soil, structures, quarantine, and stored commodities. Our meeting will deal primarily with the stored commodities section, but an opportunity will be provided for participants to comment on all aspects of the report.

The stored commodities section is divided into three marketing segments: grain storages encompassing farm, country elevator and terminal locations; grain milling and processing situations, and grain exports. Within this framework the assessment will concentrate on three specific commodities: wheat, corn, and peanuts.

There are two summary objectives of this assessment meeting. First, to establish a reasoned estimate of the postharvest use of fumigants on the designated commodities and second, to examine the overall consequences resulting from the loss of specific fumigant materials. Attaining the first objective will depend heavily on the willingness of each fumigant supplier to share marketing information of a general nature. In this regard no one is being asked to provide specific sales data of a proprietary nature. It may be questionable, however, as to whether or not any deep-dark fumigant marketing secrets are left among the few remaining players in a rapidly diminishing fumigant industry.

Obtaining information toward the second objective is to use a somewhat relevant phrase "another bag of worms". If anyone has a crystal ball, now is the time to polish it up and bring it along. Actually, one of the "loss scenarios" to be considered is in progress now, i.e., the loss of liquid fumigants. With the crosssection of expertise represented at this meeting we should be able to examine how this action is affecting the overall treatment of grain supplies, what shifts to other fumigant materials or alternative controls are occurring, and finally, to identify the "economic costs" of this action. By critically examining the reactions to the loss of liquids, perhaps we can more accurately project the consequences of losing methyl bromide, or chloropicrin, or phosphine materials, or quite possibly all three compounds.

Enclosed are tables showing production and storage date for the three principal commodities under consideration. As you will note in Table 1, with the exception of the drought period of "83" the combined wheat and corn volume in the U.S. marketing system has consistently remained near the 10 billion bushel level in recent years. Stock position figures in Table 7 confirm that nearly two-thirds of that total is typically in storage positions during the marketing year with roughly 60% stored in on-farm locations and 40% in commercial storages. Furthermore, the heavy concentration of wheat stored on farms in the northern plains and mountain states and in commercial storages throughout the Plains area is clearly evident in Table 6. On the export scene, annual corn shipments have averaged 1.9 billion bushels and wheat about 1.5 billion bushels over the past three year period.

These data together with the stock position information on peanuts (Table 2) provide the marketing parameters within which the grams and pounds of phosphine, methyl bromide and chloropicrin plus the few remaining gallons of liquid fumigant must be apportionated. If any additional information is required prior to the meeting please contact me at (913) 776-2719.

C. L. Storey

C. L. STOREY
Chairman, Fumigant Assessment Panel for Stored Commodities

Panel members:
- Phil Harein, University of Minnesota
- Herb Womack, University of Georgia
- Les Malone, Federal Grain Inspection Service, USDA
- Ron Davis, Pesticide Impact Assessment Staff, Agricultural Research Service, USDA
- Craig Osteen, Economic Research Service, USDA

Actions now pending before EPA could impact adversely on the availability of some of the common grain fumigant chemicals. Please respond to the following possible situations:

A. Loss of (carbon tetrachloride based) liquid fumigants

		ON-FARM (yes/no)	OFF-FARM (yes/no)
1. Would result in increased use of:	solids		
	chloropicrin		
	methyl bromide		
	grain protectants		
	non-chemical contents (aeration, screening, etc.)		
2. Amount of grain fumigated would:	remain the same		
	decrease		
	increase		
3. The level of insect infestation would:	remain the same		
	decrease		
	increase		
4. Insect discounts (applied by buyers of infested grain) would:	remain the same		
	decrease		
	increase		
5. Grain quality with respect to insect related damage would:	remain the same		
	decrease		
	increase		

B. Loss of solid fumigants

		ON-FARM (yes/no)	OFF-FARM (yes/no)
1. Would result in increased use of:	liquids		
	chloropicrin		
	methyl bromide		
	grain protectants		
	non-chemical contents (aeration, screening, etc.)		
2. Amount of grain fumigated would:	remain the same		
	decrease		
	increase		
3. The level of insect infestation would:	remain the same		
	decrease		
	increase		
4. Insect discounts (applied by buyers of infested grain) would:	remain the same		
	decrease		
	increase		
5. Grain quality with respect to insect related damage would:	remain the same		
	decrease		
	increase		

SECTION 3. continued

C. Loss of methyl bromide

		ON-FARM (yes/no)	OFF-FARM (yes/no)
1. Would result in increased use of:	liquids		
	solids		
	chloropicrin		
	grain protectants		
	non-chemical contents (aeration, screening, etc.)		
2. Amount of grain fumigated would:	remain the same		
	decrease		
	increase		
3. The level of insect infestation would:	remain the same		
	decrease		
	increase		
4. Insect discounts (applied by buyers of infested grain) would:	remain the same		
	decrease		
	increase		
5. Grain quality with respect to insect related damage would:	remain the same		
	decrease		
	increase		

D. Loss of chloropicrin

		ON-FARM (yes/no)	OFF-FARM (yes/no)
1. Would result in increased use of:	liquids		
	solids		
	methyl bromide		
	grain protectants		
	non-chemical contents (aeration, screening, etc.)		
2. Amount of grain fumigated would:	remain the same		
	decrease		
	increase		
3. The level of insect infestation would:	remain the same		
	decrease		
	increase		
4. Insect discounts (applied by buyers of infested grain) would:	remain the same		
	decrease		
	increase		
5. Grain quality with respect to insect related damage would:	remain the same		
	decrease		
	increase		

E. Loss of liquid fumigants and methyl bromide

		NO-FARM (yes/no)	OFF-FARM (yes/no)
1. Would result in increased use of:	solids		
	chloropicrin		
	grain protectants		
non-chemical contents (aeration, screening, etc.)			
2. Amount of grain fumigated would:	remain the same		
	decrease		
	increase		
3. The level of insect infestation would:	remain the same		
	decrease		
	increase		
4. Insect discounts (applied by buyers of infested grain) would:	remain the same		
	decrease		
	increase		
5. Grain quality with respect to insect related damage would:	remain the same		
	decrease		
	increase		

F. With fumigants gone, it is assumed that increased reliance will be placed on grain protectants and nonchemical controls.

		NO-FARM (yes/no)	OFF-FARM (yes/no)
1. Under the above situation the level of insect infestation in stored grain would:	remain the same		
	decrease		
	increase		
2. The risk of developing increased insect resistance would:	remain the same		
	decrease		
	increase		
3. Grain quality with respect to insect related damage would:	remain the same		
	decrease		
	increase		

STORED TOBACCO

BIOLOGIC AND ECONOMIC ASSESSMENT

OF

STORED TOBACCO FUMIGANTS

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ABSTRACT

In excess of 6 billion pounds of tobacco worth approximately $18 billion are in storage in the United States. Most of this tobacco is known as burley, flue-cured, cigar, Oriental and off-shore. Due to various marketing demands and the need to age tobacco, a majority of the commodity is in storage for at least 3 years. During this period the commodity can be infested with insects at almost any time. Uncontrolled infestations can result in downgrading or may render the commodity unmarketable. To prevent insect damage, almost all tobacco is fumigated once a year. In a few situations tobacco may be fumigated more than once a year.

The most commonly used fumigants are phosphine and methyl bromide. Space treatments utilizing dichlorvos are also used. Loss of one or both of the fumigants could have substantial economic impact. Presently there are only three alternative measures that the industry could use either alone or in combination: dichlorvos, methoprene, and cold treatment. These alternatives would probably have to be used in combination with each other. Such alternatives as controlled atmospheres, heat treatment, and others have not been tested sufficiently in tobacco to justify their immediate use. Other alternatives may have potential use, but few have been investigated.

The economic aspect of this report reflects not only the direct cost of the currently used chemicals, but it also examines changes in practices associated with the alternatives, the cost of labor, and the effects on quality. All of the alternatives would be more expensive than the present control practices and all would result in quality and marketability problems. If insect control and

related economics so indicated, it is quite possible that some of the processing and manufacturing facilities would be moved from the continental United States in order to maintain the quality of the raw product at a reasonable cost. Substantial local economic impacts would be felt by those involved in the production, processing, and manufacturing of tobacco. Indirect effects would also be felt in wholesale and retail marketing of tobacco products.

INTRODUCTION

A study was conducted on the impact of the loss of fumigants to the tobacco industry. In addition to presently used fumigants, the feasibility of the use of several available alternative control measures by the tobacco industry were to be investigated. The impacts of fumigant losses on insect control, tobacco quality and the economic implications of such losses were also to be studied. Various potential alternatives to fumigants were also to be studied as related to their availablity, ability to control insect pests, commercial feasibility and economic impact. Problems associated with the use of new and/or developing control technologies would also be identified.

BIOLOGICAL AND ECONOMIC INFORMATION BY COMMODITY

Major Uses

Commodity Information

Geographic distribution.--Tobacco is grown and stored in the Eastern and Southwestern United States. Tobacco production is divided into two geographic regions based on climactic conditions as related to tobacco storage and handling practices. Region I is composed of North Carolina, South Carolina, Virginia, Georgia, Florida, Tennessee, and Puerto Rico. Region II includes Maryland,

Kentucky, Wisconsin, Ohio, Pennsylvania, and Connecticut. For the purposes of this report Regions I and II have been merged (Table 1). Basically, the reasons for merging both Regions are that the insects, the postharvest insect control procedures, and the fumigation schedules are similar.

Number of units in storage.--Total processed and unprocessed tobacco in storage in the two regions amounts to 6,063,660,000 pounds (Table 2). Of this total, burley makes up approximately 2.000 billion pounds, flue cured 3.000 billion pounds, Oriental .370 billion pounds, off-shore tobacco 0.500 billion pounds, and cigar tobacco 0.182 billion pounds. Most Oriental tobacco is imported from the Near East and off-shore tobacco (burley and flue-cured) is imported from Latin America.

Value of stored tobacco.--Typically tobacco is stored for 3 years, although most of the six billion pounds in storage is available at any given time. Assuming an average price of 3.00/lb, $18 billion worth of tobacco is in storage in a given year. Cigar wrapper and binder tobaccos are a high cost product and their quality must be maintained at almost any expense. The figures shown in Table 2 are an estimate of the total tobacco in storage for a given year. This tobacco must be treated in some way annually to control insects. At the present time fumigation is the accepted form of treatment.

Postharvest insect control practices.--Fumigants used to treat stored tobacco are phosphine and methyl bromide (Table 3). Phosphine is the most commonly used fumigant. Methyl bromide is usually used only on cigar tobacco prior to manufacture. The manufacturers prefer to kill insects in less than 2 days, and this is achievable with methyl bromide but not with phosphine. All tobacco types are stored in what are termed mixed storages (warehouses); that

is, many types or classes of tobacco may be represented in one storage warehouse. Storages are generally about 550,000 cubic feet. Most storages are sealed adequately for fumigation. Openings, such as side and roof vents, are sealed with various plastic films when fumigation is required. After fumigation the sealing material is removed.

In addition to fumigants, space treatments are often used to reduce the number of flying insects. Pests may be exiting infested tobacco or entering the warehouse from an outside source (Table 4). The pesticide most commonly used is dichlorvos (DDVP) and it is released as an aerosol. The frequency of application of dichlorvos varies from location to location. Dichlorvos may be applied on a daily basis when insect flight activity is greatest or it may be applied twice a week using a higher dosage.

Tobacco storages are generally fumigated once a year. The manufacturers tend to fumigate their raw stocks during the 4th of July when the plants are closed for the holiday. The export dealers fumigate their stocks whenever insects caught in traps indicate a destructive infestation is developing. From then on, unless an alarming infestation occurs, adequate control is provided with dichlorvos space treatments. Losses may be incurred by downgrading and/or unmarketability. Methoprene and/or cold storage are used on small portions of the storages and particularly those in more northern locations (Region II) (Table 4).

Pest Information

Pests and their life cycles.--There are two major pests of stored tobacco, the cigarette beetle (*Lasioderma serricorne* Fabricius (Coleoptera:Anobiidae)) and the tobacco moth (*Ephestia elutella* Hübner (Lepidoptera:Pyralidae)). Both of these insects have certain preferences as to the types and conditions of the tobacco they will infest. Both are distributed worldwide. The cigarette beetle can damage tobacco either before or after processing and also the finished products. Damage caused by the tobacco moth is primarily in storage and not in the manufactured product. An excellent review of tobacco insects, their biology and control can be found in USDA Agricultural Handbook 233 (16).

Both insects, if left uncontrolled, can render the product unmarketable. This rarely occurs, however, as tobacco is scheduled routinely for fumigation, at least once a year. Severe damage is usually restricted to small operations where tobacco is stored on the farm. Storage or aging of tobacco is required for fermentation to improve its taste and aroma. During this aging process and throughout manufacturing and marketing, the commodity is subject to attack by stored product insects.

Both of these primary pests can be controlled with either phosphine or methyl bromide. It should be mentioned that the tobacco industry is very aware of the problems caused by these insects and does its utmost to protect the commodity from damage or losses caused by them. Buyers from domestic or foreign manufacturing companies do not buy insect-damaged tobacco or, at the very best, they buy only with a substantial discount. Insects are responsible for five types of losses in cured tobacco: 1) loss of quantity and quality of leaf

tobacco; 2) loss in value of manufactured tobacco at the manufacturer, wholesale or retail levels; 3) loss of tax revenue; 4) loss of export tobacco sales due to customer refusal, and 5) loss of consumer acceptance for a particular brand after purchase of an infested product.

Cigarette beetle.--The cigarette beetle will attack tobacco in storage, during manufacture, and at the retail level. Thus, the product is subject to continuous invasion by this pest. Perhaps the two most important factors that limit distribution of the insect are low temperatures and low humidity. In most areas of the world with tropical or temperate climates, the cigarette beetle is considered to be a pest of economic importance. The egg is pearly white, elongate-ovoid, and about 1/50th of an inch long when laid. After hatching, the insect generally completes four instars before pupating; fully grown fourth instar larvae weigh from 2.5 to 5 milligrams and are approximately 3/16 of an inch long. They tend to penetrate deeply into a commodity that is packed loosely, but generally remain in the peripheral areas in tightly packed containers, such as cases or hogsheads of tobacco strips. The published number of eggs laid per female ranges from 45 to 116; however, there is considerable variation in the number of eggs laid per female. In North Carolina, under warehouse conditions, egg deposition is heaviest the first 10 days after adult emergence and most eggs are laid on the fourth, fifth and sixth days. Under favorable conditions, eggs hatch in 5 to 10 days and the larvae mature in about 30 to 50 days. The total developmental period is 5 to 6 weeks from egg to adult. There may be no well-defined hibernation period in heated buildings or subtropical climates for either the cigarete beetle or the tobacco moth.

Practically all injury to tobacco by the cigarette beetle is caused by the feeding of the larvae. Most adults attempt to leave the tobacco soon after emergence from the pupal case; however, these insects can mate and lay eggs within a commodity without migrating to open space. This insect attacks the principal types of tobacco, including cigarette, cigar, chewing and snuff, as well as most forms of manufactured tobacco. Burley and Maryland tobaccos are less likely to be attacked, but occasionally these types are severely damaged by the insect. The larva burrows through the tobacco, making rather clean-cut holes, and leaving behind a fine powder of excrement. Flavor is impaired in infested cigars and cigarettes, which are further made unfit for smoking by the holes in the wrapper or paper which prevents satisfactory draft. The greatest dollar loss caused by the cigarette beetle occurs in leaf tobacco during storage.

Tobacco Moth.--The tobacco moth was first recorded as a pest of cured tobacco in Russia in 1915. It has been recorded as attacking many dried vegetable products and has been carried in these products to all parts of the world.

The adult is a small gray or brownish-gray moth. It measures about 3/8th of an inch from head to tips of folded wings and has a wing spread of about 5/8 inch. Sandy-white eggs are laid singly or in loose groups on or near tobacco and gradually turn darker as the embryo develops. The slightly elongate eggs weigh about 33.5 micrograms and are about 1/50th of an inch long. The tough shelled eggs are only loosely attached to the host. The larva is tiny when hatched, but after development through six instars it is approximately 1/2 inch long. Larvae reared on tobacco vary in color from yellow through browns to pinkish or white.

When full grown, the larva spins a web-like cocoon in which it transforms to a pupae. Pupae darken as they age from a light to a dark brown. The average number of eggs laid per female exceeds 100, and as many as 279 eggs have been reported from a single female. Eggs hatch in 3 to 17 days and the larvae reach maturity in 25 to 128 days, depending on temperature. The pupal stage requires from 5 to 25 days. Under summer conditions the life cycle from egg to adult averages about 50 days - 5 days for incubation, 35 days for larval development and 10 days for pupation. Adult moths live for about 7 days, although in cool weather they will survive longer.

The tobacco moth passes the winter as a larva. In the fall most of the mature larvae leave the tobacco and migrate to cracks and crevices about the building, where thy spin loose silken cocoons in which they hibernate. Some larvae may spin cocoons on or near the surface of the tobacco. Immature larvae remain inactive in the tobacco and most of these fail to survive the winter. Mature larvae are able to withstand low temperatures for long periods. Tobacco moth larvae have been reported to survive the winter in unheated buildings in Canada at a temperature of -30°F. In North Carolina and Virginia, larvae have been known to survive exposure to near 0°F for 2 to 3 weeks. The peaks of emergence of the tobacco moth are a little more sharply defined than those of the cigarette beetle. As many as three generations may occur per year.

Only larvae of the tobacco moth feeds on tobacco. This insect does not attack manufactured tobacco products. It feeds only on leaf tobacco of the flue-cured, air-cured, and turkish types and prefers those grades containing high sugar and low nicotine. Tobacco with a sugar content of more than 10 percent and a nicotine content of less than 2 percent seem particularly attractive to the tobacco moth. The larva is a heavier feeder than the

cigarette beetle larva, and a severe infestation of larvae may devour entire leaves except for the midrib and larger veins. In crawling, the larva leaves behind a silken thread that forms webbing and catches pellets of excrement. Such accumulations are unsightly and objectionable to buyers of stored tobacco. Mature larvae move to the surface or migrate from tobacco to pupate. This movement is necessary as the adult is initially fragile after emergence from the pupal case and cannot cut its way out of confinement. The moth does not mate in close confinement.

Several other insects have also been reported as infesting tobacco and may occasionally cause injury. The larger tobacco beetle (*Tricorynus tabaci* (Guerin)) is primarily a tropical species, but it has been reported in much the same way as the cigarette beetle. It resembles the cigarette beetle but is larger and black instead of brown. In addition, approximately 30 other species have been found to be associated with tobacco in warehouses or factories. Most of these recordings have been from traps as opposed to from an active infestation.

Geographic distribution.--Worldwide. The beetle attacks cereal grains and the finished product as well as unusual commodities such as chili pepper. The tobacco moth is a major pest to the chocolate industry, attacking both the raw and finished product.

Losses in absence of control.--Losses in the absence of control are very difficult to establish since the industry monitors and controls pests very well; however, it is believed that 20 percent downgrading would occur in infested tobacco the first year without control. This would increase to 40 percent the second year and 80 percent in the third year, which is usually the final year of

storage. Similarly, after one year 10 percent of the tobacco would be unmarketable, consisting of contaminated fine scrap and insect frass. After 2 years 20 percent would be unmarketable, and after 3 years, 40 percent would be unmarketable.

Use of Pesticides on Harvested Commodity

Classes of tobacco damaged by insects.--There are seven classes of stored tobacco in the United States. Within each class there are many tobacco types. Tobacco from three of these classes, flue-cured, Oriental, and cigar (filler, binder, and wrapper), are attacked by the cigarette beetle (*L serricorne* (F.)). This insect feeds throughout the tobacco mass in bales, cases, or hogsheads. Burley is another class and has types frequently damaged by this insect. Tobacco classes known as Light Air and Sun Cured, Dark Air and Sun Cured and Fire Cured seldom suffer postharvest insect damage because of their low sugar content. The tobacco moth (*E. elutella* (Hübner)) attacks stored flue-cured and Oriental tobaccos, but its damage is confined to surface areas (16).

Storage period and commodity temperature.--Damage to stored tobacco by insects is a function of a number of factors: tobacco class, commodity temperature, and length in storage. The preferred storage period for flue-cured tobacco in the United States is 2-3 years, for Oriental tobacco it is 0.5-1.25 years, for all types of cigar tobacco it is 0.5-2 years, and for burley tobacco it is 1-2 years. Commodity temperature and subsequent insect control needs are dependent on storage location. In the late 1940's, flue-cured tobacco stored in hogsheads for 6 years in South Carolina under neglected conditions was totally

destroyed by the cigarette beetle. Such extensive damage has never been recorded at storage loactions in Kentucky and Pennsylvania where colder winter temperatures slow or stop insect development; however, even in northern storage locations, insect damage to tobacco is severe if control practices, such as sanitation and application of pesticides, are not used. It is difficult for the cigarette beetle to reproduce at temperatures below 65°F or greater than 120°F (9). In the principal tobacco storage States, product temperature is between 65° and 85°F for about 6 months. During this time, three to four generations of the cigarette beetle and tobacco moth may occur.

Tobacco losses.--The typical tobacco storage building volume is 550,000 cubic feet. When filled to 70 percent capacity, the building contains approximately 3,091,000 pounds of tobacco. If left untreated during the summer season, 2,000 pounds of tobacco could be consumed by the beetle. This figure is conservative as it is based upon tobacco consumption by a larva of 11.43 mg (communication with tobacco scientist, 1985) whereas L. W. Fletcher (unpublished data) found the quantity of tobacco consumed ranged from 8.5 to 32 mg and averaged about 16.5 mg. An uncontrolled cigarette beetle population will increase several fold each additional year the tobacco is in storage. Therefore, it is understandable that under favorable conditions, such as the prevailing warm air and high humidity that occur in Charleston, SC, for example, an entire crop could be lost in 6 years of storage. Tobacco loss expressed in pounds, however, does not reflect total damage to the product. Visual attractiveness decreases drastically when tobacco leaves are perforated by insect feeding and any leaves left intact are contaminated with insect frass and exuviae. Furthermore, exported tobacco (542.7 million pounds in 1984 (18)) must be of high quality to sustain overseas markets. Tobacco sustaining insect damage, visual and/or otherwise, is either downgraded or is not acceptable to foreign markets.

Number of tobacco storages.--More than 99 percent of the tobacco grown in the United States is stored off-farm in commercially-owned warehouses. The other 1 percent remains on-farm and is not sold either because of marketing regulations or because of low price.

As previously mentioned, a total of 6,063,660,000 pounds of tobacco is in storage in a given year (18). Assuming the typical storage is filled with 3,091,000 pounds of tobacco, it is reasonable to estimate that there are about 2,000 commercial storages in the United States.

Tobacco storage location.--About 90 percent of the storages are located in States south of Maryland. For convenience, this area is identified as Region I and most tobacco stored in this region is used for manufacture of cigarettes. Tobacco stored in Region II is found predominantly in Pennsylvania and generally is used for manufacture of cigars. Other States included in Region II are Maryland, Kentucky, Wisconsin, Ohio, Pennsylvania, and Connecticut.

Storage construction.--In Region I the tobacco storages are usually of a single level design, and those in Region II frequently are older buildings with more than two levels. The storage floor is usually concrete, but there is an occasional storage with a wooden floor. Buildings with wooden floors not only are difficult to treat with chemical pesticides but they are also hard to maintain in conformity with good sanitation standards. Sidewalls of tobacco storages are usually sheet metal. There are, however, a number of storages with walls constructed of brick, concrete, or concrete block. Roofs are usually made of an asphalt- or tar-gravel composition laid on wooden planks or sheet metal. Many storages constructed in the past two decades have roofs of sheet metal painted silver in an attempt to reduce solar heating in the summer season.

Insect detection.--Detection of pest insects in storage warehouses and in processing and manufacturing plants is accomplished with traps that operate continuously when ambient temperature is favorable for flight activity. Most traps depend upon black-light (ultraviolet) as the attractant. More recently, cigarette beetle pheromone-baited traps have been used experimentally, but their efficacy for detection as compared with black-light traps is uncertain. Traps are used both to detect infested areas and to determine the intensity of infestations. Fumigants are used only when active infestations are identified.

Fumigant use and application techniques.--Cigarette and cigar dealers and manufacturers depend upon fumigants for control of insects in all types of stored unmanufactured and manufactured stocks. Stocks are fumigated only when an active infestation becomes known. Tobacco imported into the United States is routinely fumigated to prevent infestation of clean storages. Also, a receiving country may require some type of pesticide treatment prior to export of tobacco. Manufacturers of chewing and snuff tobacco also use fumigants to control insect outbreaks.

The tobacco industry uses about 25,197 pounds of actual phosphine annually (Table 3). Cost of the formulated phosphine is about $720,000. About 80 percent is used to fumigate flue-cured tobacco, 14 percent for Oriental tobacco, 5 percent for cigar tobacco, and 1 percent for burley tobacco. Many companies store flue-cured and burley tobaccos in the same building regardless of whether it was produced in the United States or off-shore. This reduces the risk of having a storage with only one type of tobacco at a single location being destroyed by insects or other causes; however, storages filled with burley tobacco alone are rarely fumigated.

About 80,000 pounds of actual methyl bromide are used annually (Table 3). Approximately 95 percent is used by the cigar industry to fumigate filler tobacco in atmospheric or vacuum chambers. Some Oriental tobacco (5 percent) is fumigated with methyl bromide under vacuum. Cost of methyl bromide fumigation and ancillary labor and materials to the industry using vacuum or atmospheric chambers is about $2.50 per 1,000 pounds of tobacco.

Flue-cured, Oriental, and cigar tobaccos, the classes most susceptible to insect damage, are fumigated using different schedules (see Appendix 1); however, in general, these three classes of tobacco are fumigated annually. These tobacco classes and various types of insect control methods that may be used to protect their quality are presented individually.

Flue-cured tobacco

Phosphine.--This class of tobacco generally does not remain in storage for periods longer than 3 years. It is fumigated annually with phosphine. New crop tobacco that is purchased for export may or may not be fumigated once before shipment. In other instances, aged export tobacco is fumigated with phosphine prior to shipment to comply with regulations of the receiving country. About 40 percent of the exported tobacco is fumigated prior to shipment to satisfy foreign government regulations.

On April 30, 1985 a farmers' cooperative with membership of more than 750,000 had tobacco stocks on hand of 805 million pounds. Of this quantity, 267 million pounds were from crop years 1976-81 (2). Although the preferred storage

period is 3 years, frequently tobacco from older crop years remains in storage. By contrast, tobacco dealers and manufacturers seldom have on hand significant amounts of tobacco older than 3 years.

Most phosphine fumigations are conducted by commercial applicators in storage warehouses that have been sealed. Usually the dosage is 20 g of phosphine per 1,000 cubic feet of warehouse volume, and the fumigation period is for 96 hours at temperatures above 68°F; aeration is for 72 hours (4). A fumigation crew of six individuals can seal and fumigate about 12 average sized storages per day provided the storages have been previously inspected and repaired for excessive leaks in the building structure. A three-person crew can open about 24 storages per day for aeration. This includes pick-up and disposal of the spent formulation. Tobacco storages are located throughout much of the tobacco-growing areas, and the number of storages at a location varies from 1 to 40. Because many storage locations have less than 24 storages, crew operational efficiency is decreased because of travel time spent between storage locations.

Approximately 40 percent of the exported flue-cured tobacco is fumigated prior to shipment to satisfy requests from buyers. Thirty-eight of the 40 percent is fumigated with phosphine and approximately one-fourth of the fumigations are performed in 20- or 40-foot container vans. In vans the phosphine dosage is 33 g per 1,000 cubic feet and the fumigation period is for 4 days or more depending upon temperature of the tobacco (5). A two-person fumigation crew can apply the fumigant, seal the van doors with tape, and post required safety placards on the van in about 12 minutes. The same size crew can open the van for aeration, remove tape, and dispose of the spent formulation in 4 minutes. The remaining tobacco consigned for export is fumigant with phosphine in warehouses or very large atmospheric fumigation chambers.

Alternatives to phosphine.--Alternatives to phosphine for protection of flue-cured tobacco quality are:

Methoprene--a chemical pesticide that restricts insect development (primarily larval) which is very effective in preventing reproduction (12, 13). The pesticide is applied at 5 ppm to tobacco at the end of the redrying process, before the commodity is packed into a container for storage. Cost of equipment is 10-50 thousand dollars per redrying machine, and the total cost of the treatment is about $0.83 per 1,000 pounds of tobacco. Equipment for measurement of methoprene concentration on tobacco is required for uniform application.

Methoprene's persistent residue is advantageous for good insect control; however, care must be exercised when applying it to avoid residues in excess of established levels. The material must be applied uniformly to tobacco for good insect control and safety. Although methoprene is registered for use in the United States, the tobacco industry has not used this material widely because of the availability of space fumigants and the persistence of residues. Methoprene-treated tobacco occasionally may show a very slight amount of larval feeding and consequent damage.

Methyl bromide--a fumigant used for control of insects infesting many types of commodities after harvest. For tobacco the dosage at atmospheric pressure is 1.5 pounds per 1,000 cubic feet (7). Fumigation time is 48-72 hours, and the aeration period depends upon the air exchange capacity of the fumatorium. Usually one day is allowed for aeration. Methyl bromide is also used in vacuum chambers at a dosage of 4-5 pounds

per 1,000 cubic feet and a vacuum of 26-28 inches of mercury with a fumigation period of 4 hours. Aeration is accomplished by using two airwashes. Cost of the methyl bromide gas is about $1.00 per pound. If the fumigant were to be used for insect control in storage warehouses, cost of labor for sealing warehouses, distribution and pick-up of pressurized cylinders is similar to that incurred with phosphine.

The objections to methyl bromide are its inability to kill insects at depths greater than 9 inches in the commodity under atmospheric pressure. Also, with each fumigation there is an increase of total bromide residues (organic and inorganic) in the tobacco. Because of the established residue tolerance, the number of fumigations is limited to three. Chamber fumigation (atmospheric or vacuum) cost is about $2.50 per 1,000 pounds.

Carbon dioxide--a gas that has been used experimentally for treatment of grain and dried fruits and nuts is now being studied for control of stored tobacco insects. Basic research has shown that an exposure of 9 days to carbon dioxide concentrations of 35-90 percent is needed to kill all stages of the cigarette beetle (3). Longer exposures are required at temperatures lower than 70°F. Carbon dioxide readily penetrates tobacco bales, cases, or hogsheads. Aeration is rapid. Dry ice is the preferred source of carbon dioxide for treatment of tobacco in container vans because release of the gas can be extended over more than 3 days in insulated containers. Special techniques have been developed for sealing vans to contain carbon dioxide.

An objection to carbon dioxide is that its efficacy decreases rapidly at temperatures below 70°F. Units like container vans are difficult to seal. Retrofitting of tobacco storages for carbon dioxide retention would be difficult and expensive.

Dichlorvos--an insecticide that is released as an aerosol inside closed tobacco storages to control exposed insects. It has practically eliminated tobacco loss caused by the tobacco moth. Applications are made daily at 0.5 g per 1,000 cubic feet or twice per week at 2.0 g (6). These treatments are lethal to adult cigarette beetles not protected by tobacco or case material. Total cost of treating tobacco during warm weather (4 months) is $0.53 per 1,000 pounds of tobacco.

A major objection to dichlorvos is that it does not penetrate raw or packaged commodities. The current practice of rapid conditioning of tobacco for storage allows some insect survival. This occurs because the tobacco is in the redrying machine for only 2.5 to 4 minutes. Living cigarette beetles packed inside ceases or hogsheads of tobacco create "center infestations" within a year. If the infestations survive for 2-3 years, a 2- to 3-hundred pound core of tobacco can be destroyed. Dichlorvos will not control these infestations.

Cold treatment--a method for cooling tobacco storages during the winter season by drawing cold outside air into storages with temperature-controlled fans is in the developmental stage. During the winter season the tobacco temperature is not allowed to exceed 40°F for not less than 5 weeks. This kills cigarette beetles infesting tobacco hogsheads, cases, or bales. For the average-sized tobacco warehouse, the cost to retrofit

the storage is \$32,000 (fans, \$10,000; increase size of side vent opening, \$1,000; fan control, \$1,000; white paint, \$12,000; insulation, \$8,000). Cost of electricity to power the fans per winter season is \$300 (1).

This system has been designed with the aid of computer models. The system's accuracy has been confirmed by measured readings except for verification of the influence of white paint and insulation on the maintenance of cold temperature. The ambient winter air circulation method will not provide adequate control at latitudes lower than about 33.5 degrees (10).

Low oxygen--atmospheres containing less than 1 percent oxygen are efficacious against insects infesting stored almonds, raisins and grain (14). As with carbon dioxide, storage warehouses would be difficult and expensive to seal adequately to prevent dilution by entrance of outside air (21 percent O_2) into a sealed storage with atmospheres of low oxygen. Warehouse specifically retrofitted to retain a low-oxygen atmosphere are probably the most feasible structures for low-oxygen treatment of tobacco.

Objections to this treatment include the meticulous sealing of the fumatorium and exposure period of several days to kill insects. As with carbon dioxide, length of exposure must increase as temperature decreases for insect kill.

Heat treatment--a processing method used to moisture-condition tobacco for storage also kills insects. To increase efficacy, the processing time would have to be increased from the current 2-1/2 to 4 minutes to not less than 6 minutes (10).

There are several disadvantages to the use of heat treatment. One is slowing the flow of tobacco through the various chambers of the 125 foot machine, which increases energy consumption and significantly reduces the processing rate. Redrying plants would have to be redesigned and(or) older plants returned to activity to process the volume of tobacco produced in the United States. By slowing the process and heating the tobacco to a higher temperature, leaf color may be changed to a darker brown.

Gamma radiation--a method that has been examined but not developed for treatment of tobacco when it is moisture-conditioned for storage. Little research has been done to determine 1) whether gamma radiation affects tobacco quality, and 2) the dosages needed to prevent tobacco insect pest development.

Objections to the use of radiation include cost of the units, site location in regard to the redrying machine, and perceived danger to employees. Processed tobacco packed in bales, cases, or hogsheads would require some type of preventive treatment or physical barrier to prevent insect reinfestation during its storage life.

Biological control--predacious mites are frequently found in tobacco infested with the cigarette beetle or other insect pests. The mites

destroy a number of insect eggs, but have not been known to hold an active infestation in-check. Disadvantages of the predacious mites are that their existence depends upon a thriving pest infestation for an adequate food source and the species commonly found in tobacco storages secrete a toxin that is irritating to the skin of humans.

Although not used in commercial storages, strains of *Bacillus thuringiensis* are registered for protection of on-farm tobacco for tobacco moth control (17). Another biological control agent that occasionally occurs in tobacco is a pathogenic strain of *Bacillus cereus* (15). Tobacco hogsheads, especially those with severe center infestation, have been freed of living insects by this bacterium (8). Other micro-organisms have also been isolated from tobacco insects but have not been exploited for use.

Oriental tobacco

Major production areas are Turkey, Greece, Yugoslavia and Bulgaria. This tobacco is packed in bales with dimensions of ca. 12 x 18 x 32 inches that weigh ca. 65 pounds. It is used primarily in the manufacture of cigarettes and by weight is 20-25 percent of the finished product. All Oriental tobacco is bonded. This tobacco is consistently infested with the cigarette beetle when it enters the United States. Thus, it is fumigated before manufacture during the first summer the tobacco is in storage in the United States. Normally, Oriental tobacco is stored less than 16 months.

Phosphine.--Phosphine is used to fumigate about 95 percent of the Oriental tobacco. Most fumigations are performed in storage, although some fumigations occasionally are made in atmospheric fumatoriums. The remaining 5 percent is fumigated under vacuum with methyl bromide.

Alternatives to phosphine.--Alternatives to phosphine for protection of Oriental tobacco are:

Methyl bromide--a fumigant that can penetrate to the center of the bales. Insect kill of all stages is achievable because the tobacco is loosely packed or bale size is small.

Objections to the use of methyl bromide are primarily the higher cost as compared to phosphine and increases in bromide residue in the tobacco with repeated fumigation.

Dichlorvos--the pesticide is applied as an aerosol. Minor building preparation is required prior to its application. The cost of repeated applications (1 or 2 times/week) during a summer season is similar to the cost of one fumigation. Dichlorvos does not leave a detectable residue in the commodity; however, its vapor will not penetrate a stacked or packed commodity in sufficient strength to destroy insect life.

Objections to dichlorvos are that repeated applications must be made to prevent increase of existing infestations and it will not kill insects located inside the tobacco bales.

Carbon Dioxide--a good and safe alternative but would require major changes in handling and storage facilities. Possibilities of use are:

Exporters ship tobacco in sealed container vans containing blocks of dry ice to maintain a high carbon dioxide atmosphere.

Manufacturers construct carbon dioxide chambers to treat incoming Oriental tobacco. This usage is more feasible because availability of carbon dioxide is greater in the United States than in countries producing Oriental tobacco.

Objections to carbon dioxide are the long exposure periods (up to 9 days) required to kill all insect stages; the gas is effective only when the commodity temperature is greater than 70°F; experienced labor is required to seal the fumatorium and(or) storage facility; and availability/cost of carbon dioxide at the treatment site.

Cold treatment--Oriental tobacco is received along the East Coast of the United States throughout the year. Insects in the tobacco could be destroyed by storing the bales for a brief time period inside mechanically refrigerated containers. Length of exposure would depend upon chamber temperature. Volume of tobacco to be treated would determine the chamber size and cold treatment temperature. Temperatures much lower than 32°F kill insects more quickly (11).

The principal objections to this type of cold treatment are maintenance of refrigeration equipment and large energy consumption. There is also the danger of moisture condensation (sweating) on the commodity surface after it is removed from the refrigerated chamber.

Gamma radiation--an untried method for control of insects in bales of tobacco. The bale size is suited to current technology developed for gamma radiation of some agricultural products.

Cigar tobacco

This class of tobacco is divided into wrapper, binder and filler types. Wrapper tobacco is valued at more than $10.00/pound and after curing is stored in controlled humidity-temperature rooms for quality maintenance. Binder tobacco is of less value than wrapper but is of higher value than filler tobacco. It is stored in various processed forms and usually in temperature controlled chambers. Air temperatures of wrapper and binder tobacco storages are not favorable for cigarette beetle development. Filler types are stored in conventional warehouses subject to the humidity and temperature of ambient air. Filler tobacco is packed in bales larger than those of Oriental tobacco, ca. 18 x 34 x 48 inches, and weigh about 160 pounds. Filler tobacco normally does not remain in storage for more than 2 years.

Methyl bromide.--Methyl bromide is the preferred fumigant for treatment of cigar filler tobacco. About 70 percent of cigar filler tobacco is fumigated in atmospheric chambers and the companies perform their own fumigations. Usually the dosage is 2 pounds/1,000 cubic feet and the fumigation period is 48-72 hours. The fumatoriums are aerated within hours with fans. Four to six persons are used to move tobacco into and from the chamber. Usually a chamber can be loaded in less than 2 hours and similar time is needed for unloading. One person can seal the fumatorium and release the fumigant in about 5 minutes.

Phosphine.--The remaining 30 percent of cigar filler tobacco is fumigated with phosphine. These fumigations are conducted in storage warehouses by commercial applicators. The procedure is similar to that used for flue-cured tobacco (20 g/1,000 cubic feet, 96-hour exposure, 2 day aeration).

Alternatives to fumigants.--Alternatives that may be used by the cigar industry are limited in number. Should phosphine be banned in the United States, the industry would treat the filler tobacco with methyl bromide. The reverse would occur should methyl bromide be banned. Without fumigants, the industry would probably increase use of dichlorvos as a space treatment in these storages. There is a possibility that the cigar industry would build additional gas-tight chambers and also use either high carbon dioxide or low oxygen atmosphere to kill insects. Additionally, the industry in some fashion would treat the finished product (cigars) to be assured no living insects were present. Candidate treatments most likely to be used with the manufactured product are:

Cold storage--many companies already store the finished product at 34-35°F temperature. Additional cold storage units would have to be acquired in order to store entire production for 3 weeks or longer at temperatures not to exceed 34°F. This is the minimum exposure and maximum temperature for destruction of insect life in the manufactured product.

Microwave radiation--microwave units are already used to fix the molded cigar shape before it is overwrapped with clear, plastic sheet. The treatment is rapid and kills insects by heating. After packaging, the cigars could immediately enter retail markets of be stored at 60°F.

Safety and Fumigant Use

The pesticide safety record for postharvest tobacco is outstanding. Fumigants have been used to treat storage warehouses since the mid 1940's. The tobacco industry follows treatment schedules and regulations suggested or enforced by Federal, State and local agencies. Some localities go so far as to require a watchman to be on duty during fumigation. There have been no known fatalities caused by fumigants or insecticides or time lost attributed to fumigant exposure since the mid 1960's. Cases of human over-exposure have been the result of inadequate aeration following chamber fumigation.

Impact of Loss on Industry

If fumigants were lost to the tobacco industry, the insect growth regulator methoprene would probably be selected as the replacement even though it might have effects on the whole industry. If methoprene gained acceptance, dichlorvos treatment of tobacco storages would also increase to protect any untreated stocks from insect entry and damage. Should methoprene not be adopted by industry, the industry would not only increase use of dichlorvos, but would search for economical ways to use high-carbon dioxide or low-oxygen atmospheres for control of storage pests.

In colder climates (Region II), they would also consider the use of ambient air to kill insects during the winter season. Those companies that store tobacco in Region I would consider increasing the number of storages in Region II.

The industry would also consider manufacture of the finished product in countries where fumigants are acceptable. Many of these countries have processing plants that have been built in the last two decades. Production of flue-cured and burley tobacco classes are increasing in many countries where these newer processing plants are located. It is likely that these countries could support tobacco manufacturing plants. U.S. companies might change their major manufacturing sites to foreign countries if they felt U.S. government restrictions for use of a chemical or alternative control measure were too imposing. Shift of tobacco production, processing, and manufacturing to other countries could result in an economic burden (wholesale and retail merchandising to many households throughout the United States. Shifts of tobacco production, processing, and manufacturing to other locations would be especially burdensome in those States where this industry accounts for a high percentage of the economic base.

ECONOMIC IMPACT OF LOSS OF PESTICIDES

Introduction

The annual direct cost to the tobacco industry from the loss of phosphine was approximated by the technique of budgeting. By the same technique, an estimate was also made of the impact of the loss of all chemical fumigants. Although methyl bromide is an important management tool for the tobacco industry, its use is currently limited to a small amount of Oriental tobacco (5 percent) and about 70 percent of the 182 million pounds of cigar tobacco.

Methyl bromide is a valuable tool in those portions of the industry where it remains in use because of its rapid ability to kill insects. It requires half the time of phosphine. There is no doubt that the cancellation of methyl bromide would mean a loss to the cigar portion of the industry and an overall loss of a potentially valuable tool for the whole industry; however, because of its limited use, a scenario contemplating its loss was not estimated.

Assumptions and Procedures Including Limitations

There were two basic considerations in this analysis: The annual difference in stored tobacco insect control costs, and the annual difference in the quality and marketability of tobacco under alternative schemes compared with current control methods. It was also assumed that if fumigants were lost they would be phased out gradually over a period of time and not suddenly discontinued. It was presumed that an orderly phase out would take place such that the industry would be able to adjust over time. Insect control costs were estimated by using industry cost figures, prices of private contractors, and(or) experimental data. The cost of treatment using cold storage was taken from the work of Beard et al. (1), and the cost data on controlled atmospheres was extrapolated from the work of Soderstrom et al. (14). The projected percentage of units treated by alternative treatment type was estimated by industry representatives in cooperation with USDA scientists. Multiple treatments were considered necessary and thus there was an overlap of certain treatments; however, no attempt was made to delineate specific combinations of treatments. In particular, dichlorvos alone is not considered an effective control. If insects become a problem in stored tobacco, other forms of treatment must be

used in combination with dichlorvos. For purposes of this study, losses are estimated for a specific treatment. There are several other possible treatments for tobacco postharvest insects; however, a great deal more needs to be learned about them before industry and much of the research community considers them to be practical alternatives. Only the most economic and technically viable treatments were considered in the economic analysis.

Results

Rates of application and costs of phosphine, methyl bromide (MB) and dichlorvos are listed in Table 5. Also listed are two alternatives, methoprene and cold storage, that are used infrequently by the industry for control of insects but have potential if the previously mentioned methods lose U.S. registration.

The scenarios provided in Tables 6, 7, and 8 are established technologies that may be used if the following fumigants are lost to the industry: Phosphine, Scenario 1; methyl bromide, Scenario 2; or both fumigants, Scenario 3.

Loss of phosphine.--In Scenario 1, loss of phosphine, it is anticipated that tobacco stocks protected by methyl bromide or cold treatment (winter season) will need protection from migrating cigarette beetles. This can be achieved by space treatment of storages with dichlorvos. Some companies may elect to use methoprene as the pesticide of choice. In those instances, additional treatment of tobacco stocks for control of insects would not be needed for other than for the maintenance of a good sanitation program. Some

companies would store the tobacco in the United States for less than a year, and this tobacco would probably not be treated; however, for marketing or other reasons, should the tobacco stay in storage for periods of 1, 2 or 3 years, the projected losses due to insect damage are given.

Loss of methyl bromide.--With Scenario 2, a loss of methyl bromide, tobacco companies, and primarily those in the cigar industry, would increase the use of phosphine for protection of stocks. Because many of the storages in Region II are difficult to seal adequately for phosphine, dichlorvos as a space treatment would be used more extensively to kill adult cigarette beetles. For marketing or other reasons, about 6.6 percent of the tobacco would be untreated.

Loss of phosphine and methyl bromide.--If both phosphine and methyl bromide are lost to the tobacco industry, Scenario 3, the changes in insect control programs would be similar to those listed in Scenario 1. Some companies, however, would gradually retrofit their storages to use controlled fan circulation of winter air to kill insects. Others would thoroughly seal storages so that tobacco stocks could be treated with a controlled atmosphere. Although high carbon dioxide atmospheres could be used, the controlled atmosphere of choice would probably be low oxygen. Low oxygen (less than 0.1 percent) could be achieved by using a low-oxygen atmosphere generator. A high-carbon dioxide storage atmosphere (30-90 percent) could be produced by the release of carbon dioxide from pressurized tanks.

Current Control Costs.--For the approximately 6 billion pounds of stored tobacco, it was estimated that current annual control costs are approximately $4.993 million (Table 9). The majority of tobacco is being treated with phosphine and dichlorvos.

Projected costs of alternatives.--The probable alternatives to the use of phosphine are listed in Table 10. The annual control costs under this scenario are estimated to be $7.485 million. This represents a substantial increase over the current control methods; however, the real cost to the industry is in the form of poorer control of the tobacco insects. This results in substantial downgrading, with some tobacco being unmarketable. A value of $.50 per pound was placed on the downgraded tobacco and a value of $2.70 per pound was placed on the unmarketable tobacco that would otherwise have been marketable. The alternatives to phosphine would cost the industry an estimated $154.623 million annually in downgraded product and $407.660 million annually in unmarketable product (Table 11). This represents an annual cost to the industry of $562.283 million. It was estimated that currently there is some insect damage on low-grade tobacco. As an estimate, industry representatives and USDA scientists felt that $.250 million was a reasonable approximation of current annual losses.

The total cost to the industry as a result of the loss of phosphine is summarized in Table 12. This annual cost is estimated to be $564.525 million dollars.

Should all chemical fumigants be lost, the cost of alternative controls is estimated in Table 13 to be $14.989 million dollars annually. The losses from downgrading and from loss of marketability are estimated to be $582.596 million annually (Table 14). Table 15 summarizes the estimated total annual cost from the loss of all chemical fumigants to the tobacco industry at $592.342 million annually.

Table 1. Major tobacco storing regions and states[1]

Region I	Region II
North Carolina	Maryland
South Carolina	Kentucky
Virginia	Wisconsin
Georgia	Ohio
Florida	Pennsylvania
Tennessee	Connecticut
Puerto Rico	

[1]As postharvest insect control procedures are similar for both regions, insect control will be considered for the entire commodity rather than by regions.

Table 2. Types and quantities of tobacco in storage

Quantity of tobacco stored (billions of pounds) on hand				
Flue cured	Burley	Oriental	Cigar	Off-shore
3.00	2.00	0.371,723	0.182	0.509,937
		Total = 6.063,660		

Table 3. Use information for phosphine (AI) and methyl bromide (AI) to control insects infesting tobacco

Active ingredient	Quantity of tobacco treated* (% of amount)					Total amount of fumigant used (lb)[1]					Total
	Flue cured	Burley	Oriental	Cigar	Off shore[2]	Flue cured	Burley	Oriental	Cigar	Off shore	
Phosphine[3]	100	90	95[4]	30*	100[1]	13,227	7,936	1,557	229*	2,248	25,197
Methyl bromide	0	0	5	70*	0	0	0	10,184	69,816*	0	80,000

*Cigar tobacco may be fumigated more than once per year.

[1] 0.002 g phosphine/lb tobacco.

[2] Off-shore tobacco stored in Region I.

[3] 90 aluminum; 10 magnesium; AI.

[4] Oriental tobacco in storage for less than 16 months.

Table 4. Chemical and nonchemical alternatives to fumigants presently in use and quantity of tobacco treated in the two regions

State	Alternative Control	Tobacco treated (pct)
Region I	Dichlorvos[1]	70
	Methoprene	1
	Cold Storage	0.001
Region II	Dichlorvos[1]	15
	Methoprene	0
	Cold Storage	0.001

[1] Does not serve as a fumigant as vapor fails to penetrate.

Table 5. Costs of fumigants and alternatives, methods of application, application rates and related costs

Fumigant or alternative	Method of application	Application rate (AI)	Pesticide cost per 1,000 lb of tobacco	Application cost per 1,000 lb of tobacco
Phosphine	Gas evolving from pellets, tablets rounds and plates in storage	20 gm AI/1,000 ft^3	0.19	Labor, travel, materials applicator, maintenance of facilities. 0.28
Methyl bromide	As a gas; in a chamber	1.5-4 lb for 4-48 hr depending on temperature and atmosphere NAP or vacuum fumigation system	0.25	Labor, travel, materials applicator, maintenance of facilities. 2.25
Dichlorvos[1]	Aerosol	4 g/week	0.35	0.05[2] May-September
Methoprene	Spray on leaves at redrier machine discharge	5 p/m	1.00	0.02[3]
Cold storage	Forced cooling with outside air	90 days - thermostatically controlled fans	_[4]	_[5]

[1]Largest proportion of dichlorvos used on flue-cured and Oriental tobacco in Region I.

[2]Does not include cost of systems installation.

[3]Installation of spray equipment for each redryer.

[4]Energy cost to cool storage in central North Carolina is $300 annually.

[5]Machinery, preparation of building; one time cost of $32,000 for typical tobacco storage.

Table 6. Impacts of fumigant loss - phosphine

Fumigant lost	Alternative[1] control	Projected percent[2] of units treated	Projected losses		Reasons for downgrading of unmarketability
			pct downgraded	pct unmarketable	
Phosphine (Scenario 1)	Methyl bromide	25	5.0	3.0	Potential residues
	Dichlorvos[3]	90	0.5	0.1	Insect damage
	Methoprene[4]	55	2.0	1.0	Insect damage
	Cold treatment	10	3.0	1.0	Insect damage
	Untreated - loss estimates for 1, 2 and 3 years	10	20 - 40 - 80	10 - 20 - 40	Insect damage
		100 pct of scenario[5]			

[1]Some alternatives technically feasible but not necessarily used at present.

[2]Ranked on potential usage; anticipated cost and logistics to use.

[3]Prophylactive treatment; would not be used alone.

[4]Pesticide currently not accepted by most tobacco manufacturers.

[5]Does not total 100 percent, as more than one alternative may be used in a control program.

Table 7. Impacts of fumigant loss - methyl bromide

Fumigant lost	Alternative control	Projected percent of units treated	Projected losses		Reasons for downgrading of unmarketability
			pct downgraded	pct unmarketable	
Methyl bromide (Scenario 2)	Phosphine	95.0	0.5	0.1	Insect damage
	Dichlorvos[1]	60.0	20.0	7.0	Insect damage
	No treatment	6.6	20 - 40 - 80	10 - 20 - 40	Insect damage
		100 pct of scenario[2]			

[1]Dichlorvos would continue to be released as an aerosol for space treatment.

[2]Does not total 100 percent, as more than one alternative may be used in a control program.

Table 8. Impacts of fumigant loss - all fumigants

Fumigant(s)	Alternative control[1]	Projected percent of units treated	Projected losses		Reasons for downgrading of unmarketability
			pct downgraded	pct unmarketable	
All fumigants (Scenario 3)	Dichlorvos	90	0.5	0.1	Insect damage
	Methoprene	55	2.0	1.0	Insect damage
	Cold treatment	40	3.0	1.0	Insect damage
	Controlled atmosphere	25	3.0	2.0	Insect damage
	Untreated - loss estimates for 1, 2 and 3 years	10	20 - 40 - 80	10 - 20 - 40[1]	
		100 pct of scenario fumigant[2]			

[1]Average turnover in storage is 3 years; 10 pct first year, 40 pct after 3 years.

[2]Does not total 100 percent, as more than one alternative may be used in a control program.

Table 9. Estimated control costs for current insect control methods

Current method of control	Estimated pct units treated	Pounds treated	Cost $/1,000# tobacco	Total cost dollars
Dichlorvos	80.00	4,850,928,000	0.53	2,570,992
Phosphine	94.25	5,715,074,000	0.36	2,057,427
Methyl bromide - Chamber	2.42	145,986,150	2.50	364,965
Untreated	3.33	202,599,850		
Totals	100.00	6,063,660,000		4,993,384

Table 10. Estimated costs of treatments that may be used as alternatives to phosphine

Alternative methods of control	Projected pct units treated	Pounds treated	Cost $/1,000# tobacco	Total cost dollars
Methyl bromide - Space	22.59	1,369,780,794	0.45	616,401
Methyl bromide - Chamber	2.41	145,986,150	2.50	364,965
Dichlorvos	90.00	5,457,294,000	0.53	2,892,366
Methoprene	55.00	3,335,013,000	0.83	2,768,061
Cold treatment	10.00	606,366,000	1.39	842,849
Untreated	10.00	606,366,000		
Totals		6,063,660,000		7,484,642

Table 11. Loss estimate of alternatives to the loss of phosphine

Alternative methods of control	Projected pct units treated	Pounds treated	Projected pct downgraded	Pounds downgraded	Value dollars	Projected pct unmarketable	Pounds unmarketable	Value dollars	Total loss dollars
Methyl bromide	25	1,515,915,000	5.0	75,795,750	37,897,875	3.00	45,477,450	122,789,115	160,686,990
Dichlorvos	90	5,457,294,000	0.5	27,286,470	13,643,235	0.10	5,457,294	14,734,694	28,377,929
Methoprene	55	3,335,013,000	2.0	66,700,260	33,350,130	1.00	33,350,130	90,045,351	123,395,481
Cold treatment	10	606,366,000	3.0	18,190,980	9,095,490	1.00	6,063,660	16,371,882	25,467,372
Untreated	10	606,366,000	20.0	121,273,200	60,636,600	10.00	60,636,600	163,718,820	224,355,420
Totals		6,063,660,000	5.1	309,246,660	154,623,330	1.74	105,507,684	407,659,862	562,283,192

Table 12. Summary of estimated annual losses to the tobacco industry from the loss of phosphine as a fumigant

Differences in the cost of control methods:	
Alternatives	$7.485 million
Current cost	4.993
Increased cost of control	$2.492 million
Difference in quality and marketability	
Alternatives	$562.283 million
Current loss	.250
Value of quality and product loss	$562.033 million
Total annual cost	$564.525 million

Table 13. Estimated cost of alternatives to loss of all chemical fumigants

Alternative methods of control	Projected pct units treated	Pounds treated	Cost $/1,000# tobacco	Total cost dollars
Dichlorvos	90	5,457,294,000	0.53	2,892,366
Methoprene	55	3,335,013,000	0.83	2,768,061
Cold treatment	40	2,425,464,000	1.39	3,371,395
Controlled atmosphere	25	1,515,915,000	3.93	5,957,546
Untreated	10	606,366,000		
Totals		6,063,660,000		14,989,368

Table 14. Loss estimate of alternatives to the loss of all fumigants

Alternative methods of control	Projected pct units treated	Pounds treated	Projected pct downgraded	Pounds downgraded	Value dollars	Projected pct unmarketable	Pounds unmarketable	Value dollars	Total loss dollars
Dichlorvos	90	5,457,294,000	0.5	27,286,470	13,643,235	0.10	5,457,294	14,734,694	28,377,929
Methoprene	55	3,335,013,000	2.0	66,700,260	33,350,130	1.00	33,350,130	90,045,351	123,395,481
Cold treatment	40	2,425,464,000	3.0	72,763,920	36,381,960	1.00	24,254,640	65,487,528	101,869,488
Controlled atmosphere	25	1,515,915,000	3.0	45,477,450	22,738,725	2.00	30,318,300	81,859,410	104,598,135
Untreated	10	606,366,000	20.0	121,273,200	60,636,600	10.00	60,636,600	163,718,820	224,355,420
Totals		6,063,660,000	5.5	333,501,300	166,750,650	2.54	154,016,964	415,845,803	582,596,453

Table 15. Summary of estimated annual losses to the tobacco industry from the loss of all chemical fumigants

Differences in the cost of control methods:	
Alternatives	$14.989 million
Current cost	4.993
Increased cost of control	$9.996 million
Difference in quality and marketability	
Alternatives	$582.596 million
Current loss	.250
Value of quality and product loss	$582.346 million
Total annual cost	$592.342 million

RESEARCH NEEDS

Other than the above alternatives, methoprene and cold storage, no other alternatives are developed to the point of being commercially viable. Among the possible alternatives that need to be studied further as to their usefulness to the tobacco industry are the following: new chemicals, cold treatments, heat treatments, gamma radiation, low oxygen or high carbon dioxide atmospheres and biological control agents. Although some of these methods have been developed for other commodities, none have been studied extensively for control of tobacco insects on a large scale. In order for these possible alternatives to become commercially viable more basic and applied research needs to be conducted on their efficacy and effects on storage, processing and tobacco quality. Finally, in order for these potential alternatives to become viable a thorough economic analysis should be conducted to determine the impact of a shift to their use on the costs to the tobacco industry. Such studies should identify not only direct costs but also those procedures associated with changes in storage, processing or manufacturing costs resulting from the use of the proposed alternatives.

SUMMARY AND CONCLUSIONS

The United States' tobacco industry needs a means to protect its inventory of $18 billion of stored tobacco. Unchecked insect infestations can result in downgrading or total destruction of the product. The two major pests of stored tobacco are the cigarette beetle (*Lasioderma serricorne* Fabricius (Coleoptera: Anobiidae)) and the tobacco moth (*Ephestia elutella* Hübner (Lepidoptera:

Pyralidae)). Both of these insects are currently controlled by phosphine or methyl bromide. Virtually all tobacco in storage is fumigated once a year. Typically phosphine is used although methyl bromide is used in the cigar industry. Dichlorvos is also used as a space treatment throughout the year.

Insect damage manifests itself in the following manner: 1) loss of quantity and quality of leaf tobacco; 2) loss in value of manufactured tobacco; 3) loss of tax revenue; 4) loss of export tobacco sales; and 5) loss of consumer acceptance. It currently costs the industry an estimated $4.993 million to protect its crops using phosphine or methyl bromide and dichlorvos. There are a number of potentially useful alternatives but at this time most are neither economically or technologically feasible. Two possible exceptions are the use of methoprene, a chemical pesticide that restricts insect development, and the use of cold storage. If the industry were no longer able to use phosphine, it is likely that methyl bromide, methoprene, and cold storage would be substituted for it. The increased cost of control would be approximately $2.5 million. In addition, several of these methods might have to be combined to provide adequate insect control. However, increased losses due to reduced quality and marketability would amount to $562.0 million. Should all chemical fumigants be lost the cost to the industry would be approximately $592.34 million.

The loss of all chemical fumigants would indeed prove costly to the tobacco industry. Yet, the loss of phosphine alone would prove to be nearly as serious a problem because the industry relies so heavily on its use. It should be kept in mind that the sudden loss of either phosphine or all chemical fumigants could prove to be very disruptive to this industry. Management would have to adjust production processes, alter product flow, possibly change marketing strategies, and make necessary changes in existing structural facilities. There is no easy

way to estimate the cost that such sudden disorder might bring. Without chemical fumigants, management flexibility would be substantially reduced. If chemical fumigants were prohibited in the United States, and if the rest of the world were left with the use of chemical fumigants, the United States' tobacco industry would be at a substantial disadvantage. It is conceivable that firms might relocate abroad, shifting tobacco production and processing to countries with less stringent fumigation control and regulation. This could exacerbate an already unfavorable balance of trade. For the tobacco industry, there is no single panacea to chemical fumigants and at the present time the alternatives would prove expensive.

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COMMODITY, STORAGE, AND PEST	INSECTICIDE OR TREATMENT	TOLERANCE *(p. p. m.)*	DOSAGE *(active ingredient per 1,000 cu. ft. unless otherwise stated)*	HOW, WHERE, AND WHEN TO APPLY	SAFETY RESTRICTIONS
TOBACCO Raw or Manufactured					
In storage: Cigarette beetle (_Lasioderma serricorne_)	Cold storage		-10^{0}F for 4-5 days	Insects are inactive at low temperatures and all stages eventually die.	
			10^{0}F for 8.5 days or more		
			36^{0}F for 16 days		
			40^{0}F for 12 weeks		
			45^{0}F for 20 weeks		
			48^{0}F for 32 weeks		
			$50-60^{0}$F for entire storage period		

STORED-PRODUCT PESTS

COMMODITY, STORAGE, AND PEST	INSECTICIDE OR TREATMENT	TOLERANCE (p.p.m.)	DOSAGE (active ingredient per 1,000 cu. ft. unless otherwise stated)	HOW, WHERE, AND WHEN TO APPLY	SAFETY RESTRICTIONS
TOBACCO--Con.					
In warehouses, in redrying plants and pack-houses: Tobacco moth (Ephestia elutella)	Pyrethrins		1% formulation by wt. 1 gal per 200,000 cu. ft.		
	Pyrethrins + piperonyl butoxide		0.75% pyr. + 3.75% pip. but. 1 gal. per 200,000 cu. ft.	Apply aerosol with mechanical or thermal generator weekly or more often, between 4 p.m. and midnight.	Do not drip insecticide on tobacco. Do not release aerosol near an open flame.
Cigarette beetle (Lasioderma serricorne)	Pyrethrins		1% formulation by wt. 1 gal. per 40,000 cu. ft.		Aerosols may be used against exposed insects only.
	Pyrethrins + piperonyl butoxide		0.75% pyr. + 3.75% pip. but. 1 gal per 40,000 cu. ft.		

STORED-PRODUCT PESTS

COMMODITY, STORAGE, AND PEST	INSECTICIDE OR TREATMENT	TOLERANCE (p. p. m.)	DOSAGE (active ingredient per 1,000 cu. ft. unless otherwise stated)	HOW, WHERE, AND WHEN TO APPLY	SAFETY RESTRICTIONS
TØBACCO--Con.					
In packhouses and curing sheds Cigarette beetle (*Lasioderma serricorne*) and tobacco moth (*Ephestia elutella*)	Dichlorvos		0.5-1.0 gm. weekly, or as often as necessary	Release aerosol in free space of storage shed between 5 and 12 p.m.	
	Bacillus thuringiensis		Apply according to label	Floor and walls of sheds prior to tobacco storage or on loose leaf prior to bundling.	
In redrying plant: Cigarette beetle (*Lasioderma serricorne*) and tobacco moth (*Ephestia elutella*)	Sanitation program			Before and after use of redrying plant, clean, brush, sweep, and vacuum entire plant and machines thoroughly. When plant is in operation hogsheads of tobacco remnants should be covered and kept in a screened room.	

COMMODITY, STORAGE, AND PEST	INSECTICIDE OR TREATMENT	TOLERANCE (p. p. m.)	DOSAGE (active ingredient per 1,000 cu. ft. unless otherwise stated)	HOW, WHERE, AND WHEN TO APPLY	SAFETY RESTRICTIONS
TOBACCO--Con.					
In hogsheads in warehouses: tobacco moth (Ephestia elutella)	Dichlorvos	7	1 g.	Apply as an aerosol once a week	Do not apply dichlorvos on concrete, which neutralizes its effect.
Cigarette beetle (Lasioderma serricorne)	Dichlorvos	3-4	2 g.	Apply as an aerosol twice a week.	Do not release aerosol near an open flame.
		1	0.5 g.	Apply as an aerosol daily	Do not drip insecticide on tobacco. Do not enter area treated with dichlorvos within 4 hours after application.
Hogsheads in warehouse: tobacco moth (Ephestia elutella) and cigarette beetle (Lasioderma serricorne)	Screening		Screens should be 20-mesh, made of wire 0.135 in. in diameter, or 18 mesh wire 0.02 in. in diameter. Openings between wires should be less than 0.0395 in.	Cover openings such as louvers, doors, windows, and ventilators with screen wire.	

STORED-PRODUCT PESTS

COMMODITY, STORAGE, AND PEST	INSECTICIDE OR TREATMENT	TOLERANCE (p. p. m.)	DOSAGE (active ingredient per 1,000 cu. ft. unless otherwise stated)	HOW, WHERE, AND WHEN TO APPLY	SAFETY RESTRICTIONS
TOBACCO					
In factory: Cigarette beetle (*Lasioderma serricorne*) and tobacco moth (*Ephestia elutella*)	Air screens			Mount electric fan to flow through door of receiving room whenever the door is open, to hinder flight of insects into factory.	
	Dichlorvos	1	0.5 g.	Automatic aerosol dispensing system releases set amount of aerosol at set hr. each day after work hours.	Do not release aerosol near an open flame. Do not enter area treated with dichlorvos within 4 hrs. after application.
	Heat in vacuum		140°F for 12-14 min.	Heat chambers where continuous vapor is passed across tobacco being treated.	
			160-180°F for 15 min.	Heat chamber - "Guardite" type	
	Methylbromide		1.5-2 lb.	36-48 hr. at atmospheric pressure	

QUARANTINE

THE BIOLOGIC AND ECONOMIC ASSESSMENT OF QUARANTINE FUMIGANTS

TABLE OF CONTENTS

ACRONYMS

ACGIH	American Conference of Governmental Industrial Hygienists
APHIS	Animal and Plant Health Inspection Service, USDA
ARS	Agricultural Research Service, USDA
CFR	Code of Federal Regulations
EDB	Ethylene dibromide
EPA	Environmental Protection Agency
KB	Khapra beetle
MB	Methyl bromide
OSHA	Occupational Safety and Health Administration
PPM	Parts per million
PEL	Permissible exposure level
PPB	Parts per billion
PPQ	Plant Protection and Quarantine
STEL	Short-term exposure limit
TLV	Threshold limit value
TWA	Time weighted average
USC	United States Code

INTRODUCTION

Several agricultural and non-agricultural commodities are regulated by federal, State, and foreign quarantines. The regulations are enacted to protect the importing States from the introduction of new insect, weed, or disease pests. Foreign insects invading a new location frequently become more destructive than in their native habitat because of the lack of natural enemies, other limiting ecological factors, and competition for food sources.

Quarantine measures include exclusion, inspection, and chemical treatment to eliminate arriving pests. In the absence of these measures, the agricultural products of some areas, both domestic and foreign, would not be permitted to move beyond quarantine lines. These measures have been utilized as more practical and less costly to the overall agricultural economy than attempts to eradicate or control pests after they have become established. For example, the eradication of the Mediterranean Fruit Fly in Florida in 1929-30 cost $7.5 million, not including the value of the host fruits that were destroyed. This activity lasted two years, and employed more than 5,000 laborers and 1,200 professional quarantine and field inspectors. In succeeding infestations in 1956, 1962, and 1963, eradication treatments were successfully applied over nearly 100,000 acres at a cost of $12 million (3).

The use of fumigants as a quarantine control measure is an effective means of insuring that commodities which serve as carriers are free from any undetected pest activity. Selected commodities shipped from particular pest infested

areas require fumigation for entry status into or within uninfested areas of the United States. It is relatively easy and economical to conduct fumigations in isolated treatment facilities. Fumigants are, however, toxic chemicals which can leave residues on treated products. Because of public health concerns, the use of fumigants in quarantine programs is subject to pesticide regulatory actions.

Two fumigants materials have been or are currently being used extensively in domestic and foreign quarantine programs: ethylene dibromide (EDB) and methyl bromide (MB). In the sections that follow, the legal basis, biological factors, occupational concerns, alternative control technologies, and benefits of current fumigant use are discussed. This report examines the biological and economic impacts of the possible cancellation of fumigants used for regulatory and quarantine treatments on several selected commodities. The selected commodities include fresh citrus from Mexico, Texas, and Florida; deciduous fruits from Chile; mangos from Haiti and Mexico; cherries from Washington; papayas from Hawaii; and Khapra bettle cargo from Asia and Africa.

LEGAL BASIS: U.S. QUARANTINE TREATMENTS

U.S. quarantine treatment are legally mandated by authority of the Plant Quarantine Act of 1912 as amended (7 U.S.C. 151-167) and the Federal Plant Pest Act (7 U.S.C. 150aa-150jj) through quarantines and administrative instructions and regulations issued thereunder. Fumigant treatments are specifically required under 7 CFR for Mexican Fruit Fly Quarantine (part 301.75-4), Hawaiian Fruits and Vegetables (Part 318.13-4), Fruits and Vegetables from Puerto Rico

and the Virgin Islands (Part 318.58-3), Fruits and Vegetables (Part 319.56-2), and Khapra Beetle (Part 319.75-4). Quarantine requirements are issued and amended according to procedures specified in the Acts requiring public hearing and lengthy administrative procedures.

FUMIGANT USE IN QUARANTINE PROGRAMS

Two fumigants used extensively for domestic quarantine purposes are EDB and MB. EDB has been the principal fumigant approved for treating a variety of fresh fruits and vegetables as a quarantine measure. It has been used effectively against several species of tropical fruit flies, especially *Ceratitis capitata* (Wied.), the Mediterranean Fruit Fly or Medfly; *Anastrepha ludens* (Loew), the Mexican Fruit Fly; *A. fraterculus* (Wied.), a South American Fruit Fly; *A. suspensa* (Loew), the Caribbean Fruit Fly; *A. mombinpreaoptans* (Sein), a West Indian Fruit fly; *Dacus dorsalis* (Hendel), the Oriental Fruit Fly; *D. cucurbitae* (Coquillett), the Melon Fly; *D. tryoni* (Froggatt), the Queensland Fruit Fly; *Rhagoletis cingulata* (Loew), the Cherry Fruit Fly; and other flies of the *Ceratitis*, *Anastrepha*, *Dacus*, and *Rhagoletis* genera (CFR 319.56).

MB has been the principal fumigant used for treating fresh fruits, vegetables, and other agricultural and non-agricultural products for plant pests other than tropical fruit flies. It is mostly used to treat Chilean fruits and Khapra beetle (KB) cargo. MB fumigation is required as a condition of entry for grapes and various stone fruits imported from Chile. This regulation is based on the presence and the inspectional results over many years for a complex of insects and mites including *Proeulia* sp. (Tortricidae) larvae, *Leptoglossus chilensis*

(Coreidae) adults, Megalometis chilensis (Curculionidae) adults, Naupactus xanthographus (Curculionidae) adults, Listroderes subcinctus (Curculionidae) adults, Conoderus rufangulus (Elateridae) adults, and Brevipalpus chilensis (Tenuipalpidae) mites. It is also approved for the treatment of Mexican citrus infested by A. ludens (Loew), the Mexican Fruit Fly.

MB treatment is also required as a condition of entry for treating commodities originating in areas infested by the Khapra beetle, Trogoderma granarium (Everts). These commodities include seeds of the plant family Curcurbitaceae, cumin seeds, dried peppers, goatskins, lambskins, sheepskins, brassware, wooden screens, bulk plant gums, and jute or burlap used in bagging, wrapping, or packing cargo from several southeast Asian and African countries.

EDB Usage

Prior to September 1, 1984, EDB was registered as a commodity fumigant for control of insect pests infesting citrus, pineapples, guavas, papayas, mangos, cucumbers, bell peppers, bitter melons, Cavendish bananas, zucchini squash, string beans, litchi nuts, plums, and cantaloupes. On September 1, 1984, EPA cancelled the registration of EDB as a post-harvest fumigant in the U.S. for all citrus fruits, papayas, mangos, and other fruits and vegetables, except when used as a quarantine fumigant for exported citrus fruits and papayas. The tolerances established by EPA in 40 CFR 180.397 for residues of EDB per se in or on papayas and citrus fruit also expired on September 1, 1984. Subsequently, the tolerances established by EPA in 40 CFR 180.146 for residues of total combined bromine and for residues of inorganic bromides in or on plums and

certain other tropical fruits and vegetables (but not on mangos) fumigated with EDB expired on January 23, 1985.

EDB treatments are no longer approved by USDA as a condition of movement of certain fruits and vegetables into the U.S. or interstate as a result of EPA actions. Mango fumigations with a residue tolerance level of 30 ppb continued for fumigations under USDA supervision in Mexico and Haiti from September 1, 1984 until the cancellation of the tolerance on September 1, 1985. 1/ Delays were encountered in achieving the tolerance level at 30 ppb, especially from Haiti, and little fumigated fruit could reach the tolerance level within the shelf life of the mangos.

After September 1, 1984, papayas and citrus fumigation with EDB has been permitted for use on fruit to be exported from U.S. primarily to Japan. 2/ The treatment period for citrus, essentially grapefruit from Florida, was limited for the period October-January, but was extended through May for the 1985

1/ On February 14, 1986, a final rule was issued by EPA which reestablished an interim tolerance level of 30 ppb of EDB residue per se on mangos resulting from the fumigation of this commodity in accordance with USDA quarantine regulations.

2/ Also on February 14, 1986, a label amendment for the use of EDB only as a post-harvest fumigant of fresh citrus fruits for quarantine control of fruit flies was accepted by EPA. This amendment allowed for treatment of specified quantities of citrus in Florida for export with a graduating lessening of the quantities until June 30, 1989.

season. Papayas treatments for export to Japan are all conducted in Hawaii and have continued to date. EDB is use for this purpose only in accordance with USDA recommendations and instructions for these specific quarantine programs. Fumigations are conducted only with the approval and supervision of proper USDA authorities. Approved EDB fumigation schedules were developed to provide effectiveness equivalent to probit 9 (no more than three survivors of 100,000 test specimens) (2). Necessary dosages and commodity tolerances make the probit 9 level one of the factors limiting the availability of alternative controls.

EDB quarantine treatments are carried out in gas-tight fumigation chambers constructed and operated in accordance with the provisions of Quarantine 56 (7 CFR 319.56). Dosage rates vary from eight to 16 ounces per thousand cubic feet depending on insect species involved, temperature and fruit load in the chamber. The fumigant is introduced into the chamber liquid state onto a suitable heating implement for volatilization. Forced circulation is required throughtout the fumigation period. The exposure period of EDB treatments is two hours from the time the liquid is volatilized. Quarantine specifications call for the use of technical grade EDB of at least 97 percent purity. At the end of the fumigation period, fresh air is drawn from the outside through the load and the vapor is exhausted through the circulation system to the outside.

In 1977, EDB quarantine treatments were applied to 569.7 million pounds of domestic fruits, with about 83,500 pounds of EDB used for the treatments. In the 1981-85 shipping period, this amount had decrease to about 3,900 pounds for citrus treatment in Florida and 1,600 pounds for papaya in Hawaii per year (7).

Personnel exposure to EDB is limited by various procedures and engineering developments in recent years which assure compliance with EPA and OSHA regulations. The Florida fumigation facilities employ closed application systems in which compliance with the recently prescribed labeling requirements as follows:

1. At the State fumigation chambers, installation of a cable or any other suitable implement for opening the chamber door that will place the individual at least 10 feet from the door.

2. The systematic monitoring of EDB levels at each facility using:
   (a) OSHA-approved methods and/or portable gas chromatographs; and
   (b) the operation of an infrared analyzer equipped with an alarm system.

3. Operation of exhaust equipment in the trailers at the port for a minimum of 15 minutes prior to opening the doors. The blower will circulate 2,00 cubic feet of air per minute and result in a minimum of 15 air exchanges before the trailer doors are opened.

4. Where deficiencies exist, operators of warehouses in which fumigated fruit is stored will initiate the necessary procedural changes and/or engineering modifications to comply with all OSHA requirements.

5. Operator breathing zone levels for forklift drivers shall comply with OSHA requirements through the use of engineering modifications and/or personal protective equipment.

6. EDB-treated fruit will be transported only aboard seagoing vessels that are equipped with a ventilation system in the ship's hold in which the fruit is stored. The ventilation system shall be in operation during the loading.

The fumigation of fruit for export in containerized trailers continues without the above restrictions, although all necessary precautions are applied.

MB Usage

In FY 1984, approximately 149,000 pounds of MB were used in quarantine treatments. Two treated commodity groups comprised more than 90 percent of the total MB used, 66,700 pounds to treat 12,000,000 cases of fruit from Chile and 80,100 pounds to treat 169,000 units of cargo ranging from individual containers to barges and warehouses for KB contamination (8). Cherries in Washington and Oregon for export to Japan were treated with about 1,700 pounds. Nursery stock and other propagative material at APHIS inspection stations and recently small amounts of Mexican citrus account for the remainder.

MB quarantine treatments are carried out in gas-tight fumigation chambers or polyethylene-covered enclosures constructed in accordance with the provisions of Quarantine 58 (7 CFR 318.58), Quarantine 56 and 75 (7 CFR 319.56 and 319.75) and the Plant Quarantine Treatment Manual (9).

Dosage rates vary from 16 grams per cubic meter (16 ounces per thousand cubic feet) to 240 grams per cubic meter from two to 72 hours. Dosage and exposure time vary depending on plant pest, commodity, and temperature. MB is introduced into the enclosure from slightly pressurized cylinder through a volatilizer to ensure entry of the fumigant in the gaseous state. Fan circulation of the mixture is required for the initial 30 minute fumigation period to assure even distribution. Quarantine specifications require the use of 100 percent MB. The odorizer chloropicrin is not approved because of phytotoxicity and lack of stability. The gas is removed from the enclosure immediately after the end of the fumigation period. Fresh air is drawn through the load and the vapor is exhausted to the outside.

Treatments are applied under APHIS supervision by certified pest control operators. Product labeling and treatment manual procedures are observed. Exposure to personnel is most likely during application of the fumigant into the enclosure and while handling the product after fumigation. Strict adherence to procedures and proper use of safety equipment including the self-contained breathing apparatus, limits exposure during application. Exposure at the conclusion of treatment is limited by stringent aeration procedures which have been revised recently to assure that exposure levels will not exceed permissible limits (10). The current OSHA permissible exposure limit (PEL) for MB is a ceiling of 20 ppm. The PEL value is not to be exceeded at any time during the workday and applies exclusively to employee exposure by inhalation.

ACGIH Threshold Limit Values (TLVs) published in 1968 is also a source of occupational exposure standards. The 1968 ACGIH TLV for MB is 5 ppm with a

short-term exposure limit (STEL) of 15 ppm. A STEL is defined as a 15-minute TWA of 15 ppm. The 1983 TWA is within the TLV limits. This lower value may be accepted by OSHA in the near future.

Approximately 0.78 person-year divided among about 25 pest control operators are involved in Chilean fruit fumigation per season (8). Approximately 1.9 person-years divided among about 100 officers and 19 person-years divided among 50 pest control operators are involved in KB fumigations. Approximately 3 officers and 20 fumigation applicators and fork lift operators are involved in 20 treatments of cherries for export to Japan during the month of June in any one year. Occasional involvement with individual treatments is experienced by an additional 40 officers during treatment of other cargo and nursery stock during a typical year.

Cherries are the only commodity packed and sorted after MB treatment in the U.S. There are five fumigation facilities in the Northwest that fumigate cherries destined for export to Japan. The method for processing cherries for export to Japan varies from one fumigation facility to another. In general, three separate operations are involved: fumigation, aeration and sorting and packing. The cherries come from the field in boxes of various dimensions depending on location and are loaded directly into the fumigation chamber. After fumigation and aeration, the cherries are moved into a cold storage room or run through a hydrocooler before packing. At one location the fruit is hydrocooled before fumigation.

Before packing, the cherries are processed across a series of rollers and belts where they are cleaned and culled. This cleaning and culling procedure is a labor intensive step and there may be from 50 to 200 workers involved, including State and Federal Agricultural Inspectors. Although exposure data are limited, the most recent study shows permissible exposure levels are complied with in nearly all instances and that protective respiratory equipment can be used during application or emergencies to assure compliance at all times (11).

ALTERNATIVE QUARANTINE CONTROL TECHNOLOGIES

Vapor Heat

Vapor heat is approved by the USDA for treatment of some citrus and mangos imported from Mexican Fruit Fly infested areas and for bell peppers, eggplants, papayas, pineapples (other than smooth cayenne), tomatoes, and zucchini squash imported from areas infested with Mediterranean, Oriental, and Melon Fruit Flies. The procedure is a lengthy one as follows:

1. For Mexican Fruit Fly (*Anastrepha ludens*):

   Grapefruit, orange, tangerine, mango: temperature of fruit gradually raised by saturated water vapor at 110° F until the approximate center of the fruit reaches that temperature in eight hours, then held at 110° F for an additional six hours.

<u>Alternate procedure for orange and tangerine:</u> Temperature of fruit raised by saturated water vapor at 110° F until the approximate center of the fruit reaches that temperature in six hours, then held at 110° F for an additional four hours. The raising of the temperature of the fruit to 110° F must be rapid in the first two hours; gradual in the next four hours.

2. For Mediterrean Fruit Fly (*Ceratitis capitata*), Oriental Fruit Fly (*Dacus dorsalis*), Melon Fly (*Dacus cucurbitae*):

   Temperature of articles raised by saturated water vapor at 112° F until the approximate center of the fruit reaches that temperature within a period of time designated by the inspector. It is held for eight and 3/4 hours, then immediately cooled. Commodities other than papaya should be tested to 112° F exposure to determine tolerance before commercial treatments are attempted.

   Pretreatment conditioning is an optional prelude to the required treatment, such conditioning being a responsibility of the shipper and in accordance with necessary procedures. For example, it is the practice to condition eggplants at 110° F at 40 percent relative humidity for six to eight hours.

The vapor heat treatment was among the first to be approved for fruit fly control in the early thirties. However, its high energy demands, length of treatment (approximate 16 hours), and the impracticality of handling large volumes of fruit were the primary reasons for the development of EDB treatments.The current need for resource conservation makes the vapor heat process even more impractical.

A quick "run-up" vapor heat treatment is approved for papayas by heating with a saturated water vapor until the temperature at the approximate center of the fruit reaches a minimum of 117° F. The total treatment time including conditioning may vary from four to eight hours.

Vapor heat has a number of additional disadvantages, primarily its adverse effect on the quality and salability of the fruit. Sinclair and Lindgren (6) reported vapor heat treatments altered the taste of citrus fruits and produced off-flavors. Heat treatments destroy the fresh and delicate flavor and reduce the acidity of treated navel oranges. Others have reported effects on quality that vary somewhat according to product, maturity, season, and accurate application of the process.

Vapor heat treatments in papayas may result in damage to blemished or misshaped fruit due to improper applications. The damage mainly consists of rotting from the center of the fruit outward and usually cannot be detected until the fruit is opened by the consumer. This rotting could occur in about 50 percent of the fruit formerly treated with EDB. Consumers may buy fruit in this condition once or twice and then stop buying fresh papayas.

The alternative for the papaya processors would be to vapor heat treat only unblemished and well-shaped fruit or about 50 percent of the fruit currently treated with EDB. It may be possible to increase the percent of fruit acceptable for vapor heat treatment by more intensive management of papaya groves to insure the production of more suitable fruit. More intense management would probably mean increased pesticide and/or growth regulator use

so as to reduce the percent of blemished and misshaped fruit. Examination of these alternatives was beyond the scope of this study and require extensive research by tropical fruit scientists.

APHIS, PPO treatment schedules permit EDB or vapor heat treatments on mangos. In practice, only certain mango varieties can tolerate vapor heat. Mango varieties currently imported into the U.S. have not been tested to see if they can withstand vapor heat treatment. It is assumed that, there would be no immediate alternatives to EDB fumigation on imported mangos until testing had been carried out. Over the longer run, foreign producers would probably switch to mango varieties which could be successfully treated with vapor heat.

Hot Water Dip

A double hot water dip treatment was approved on August 29, 1984 for use as a condition for certification of papayas one-fourth ripe or less from Hawaii. This treatment has been the sole treatment for papaya destined for the U.S. mainland. The treatment is applied as follows:

> Papayas that are determined from measurements taken with an approved colorimeter to be 1/4 ripe or less may be treated with the double hot water dip if the treatment is completed within 18 hours after harvest and if the papayas are kept at an ambient temperature of 65° F (18.3° C) or above until treated. Papayas must be submerged in an approved hot water tank with four inches of water heated to a temperature of 107.6° to 109.4°F (41° to 43° C) for 40 minutes above the top layer. The water temperature

must be attained within five minutes of dipping the papayas in the first hot water tank. Within three minutes after completion of the first hot water dip, the papayas must be transferred and submerged for 20 minutes in a second approved hot water tank with four inches of water heated to a temperature of 118.2° to 121.8° F (48° to 50° C) above the top layer. The temperature of the water must be attained within three minutes of dipping the papayas in the second hot water tank.

Cold Treatment

Cold treatment is an accepted method for the treatment of citrus, grapes, apples, pears, and several stone fruits known to be fruit fly hosts from several foreign countries. The method was approved by Japan for citrus imported from the United States in 1984.

Exposing infested fruit to temperatures of 36° F (2.2° C) or below for specified periods results in the death of certain tropical fruit flies. The approved schedules for specific insects and commodities is as follows:

For *Ceratitis capitata*	10 days at 32° F or below,
	11 days at 33° F or below,
	12 days at 34° F or below, and
	14 days at 35° F or below.
For *Anastrepha ludens*	18 days at 33° F or below,
	20 days at 34° F or below, and
	22 days at 35° F or below.

For other species of Anastrepha ... 11 days at 32° F or below,
13 days at 33° F or below,
15 days at 34° F or below, and
17 days at 35° F or below.

For Dacus tryoni .... 13 days at 32° F or below and
14 days at 33° F or below.

The application of this treatment varies by commodity. For example most tropical and some subtropical fruits including mangos and papayas do not tolerate this treatment as well as citrus. Some citrus originating in certain areas may be treated but serious questions arise in the case of grapefruit. Grapefruit susceptibility to chilling injury varies throughout the season. The peak demand for Florida grapefruit in Japan occurs in late spring and early Summer, the wrong time of the year to use cold treatment on grapefruit. Injury at 32°F is minimal until December with an almost exponential increase throughout the rest of the season when Japanese demand is heaviest (4). Several shipments in the 1984-85 season confirmed this difficulty. Damage of this kind could result in the loss of about 20 percent of the treated fruit by the time it reaches the consumer. In addition, treatment facilities are not available in Florida, Texas or Mexico and would have to be constructed and approved before shipments could be initiated.

The combined use of fumigants, phosphine or MB, plus low temperatures have been experimentally tested on citrus. None of these experiments have proven to be satisfactory and practical. The time required for registration and approval by

USDA, State, and foreign governments precludes their consideration as practical alternatives at this time.

Fly-Free Zones and Eradication Programs

An area treated and surveyed to indicate the absence of tropical pests (equivalent to probit 9 security) is known as a "Fly-Free zone". No area so designated presently exists, although draft protocols have been proposed for parts of Florida, Texas, Mexico, and Brazil.

Eradication programs consist of concerted efforts to eliminate certain target pests from wide areas. The success of eradication programs rely heavily on their biological, economic, and technical feasibility. Although no pesticide treatments are involved at the time of shipment after the successful implementation of both alternative control programs, manpower needs and material costs for pesticide applications and pest surveys are basic program components and no accurate estimates exist.

Irradiation

Irradiation using ionizing irradiators to kill or sterilize pests has been proposed for many quarantine applications. To date it is classed as a food additive by the FDA and FDA's approval as such and its potential future uses are pending. Irradiation treatments have applicability to several commodities should such approval be forthcoming.

QUARANTINE CONTROL BENEFITS TO SPECIFIC AREAS AND CROPS

Florida

Japan requires all fresh citrus from Florida to be fumigated prior to shipment because of the Caribbean Fruit Fly. EDB has been used since the 1950's for this purpose and is presently approved for use during the months of October through January of the shipping period. Since 1972, Japan has become a major market for U.S. fresh grapefruit exports. Most of the exports have been white, seedless varieties produced in Florida. During the 1975-76 and 1976-77 seasons, exports of fresh grapefruit from Florida to Japan represented 73 percent and 82 percent of total Florida fresh grapefruit exports, excluding Canada, respectively (4). Since then, exports have fluctuated depending on market and weather conditions. In 1984-85,4,852,269 4/5 bushel cartons of 42 pounds each were shipped, valued at approximately $33,000,000. EDB or MB treatments of Florida citrus destined to California, Arizona, and Texas has been halted because of the presence of citrus canker disease infestation.

Japan has approved the use of cold treatment and recently MB on an experimental basis. The experimental use of cold treatment during the 1984-85 season was not completely successful. Shippers and recievers are reluctant to continue it without additional evidence of its effect on fruit condition and shelf-life. MB is known to damage citrus in many circumstances and testing is currently in progress to determine the extent of its practical use.

Immediate alternatives involve the use of cold or MB treatments. Either alternative would result in a projected significant change of quality in the final product resulting in lower prices or less volume shipped. Irradiation, the fly-free zone concept, and eradication via release of sterile male flies are alternative control technologies for the future. The fly-free zone concept and irradiation treatments could become operational within five years. Eradication is a longer-term objective.

Hawaii

The quarantine imposed because of the presence of three tropical fruit flies, C. capitata, D. cucurbitae, and D. dorsalis, in Hawaii requires the treatment of their fruit and vegetable hosts. Bitter melons, Cavendish and Hawaiian bluefield bananas, apple bananas, green cooking bananas, cucumbers, fresh litchi fruits, pineapples (other than smooth cayenne), string beans, zucchini squash, and papayas are required to be treated before movement from Hawaii. Papaya is the only fruit treated since the restriction of EDB. More than 50 million pounds of fresh papayas valued at nearly $6.9 million (FOB, Hawaii) were shipped to the U.S. mainland or exported to Japan during FY 1984 (5). Approximately 85 percent of that quantity was destined to the mainland since local consumption of papayas reached the market saturation level years ago.

Papaya production increased by one-third in Hawaii during the five-year period from 1980 to 1984, rising from a total of about 49 million pounds in 1980 to 67 million pounds in 1984. Nearly all papaya produced in Hawaii are utilized as fresh fruit and only a small percentage is utilized for processing (16.7 percent

of total production in 1984). In recent years, about 80 to 85 percent of the production has been exported. All markets available to Hawaii are free from fruit fly infestation and, therefore, all papaya shipments are regulated (1).

The Ripeness Index hot water dip treatment is presently used for certification of papaya shipped to the U.S. mainland, EDB treatment is required for certification to Japan. The hot water treatment produced some problems relative to unripened "hard spots" in the fruit, but recent improvements in its application have alleviated that problem. EDB use may soon be subjected to restrictions by the Japanese Ministry of Health. Should the use of EDB be terminated, the double hot water dip, irradiation, or hot water dip plus MB fumigation are possible alternatives. Vapor heat treatments may not be conducted due to a present lack of facilities. Irradiation is subject to FDA approval and some research on commodity tolerance is necessary but could be available in the near future. Hot water plus MB is in the experimental stage and some fruit damage is likely with its use.

Texas

The Mexican Fruit Fly quarantine requires the treatment of all host fruits of A. ludens and related species indigenous to Mexico from infested areas of Texas, if such fruits are moved to or through the States of Arizona, Florida, California, and Hawaii; the Parishes of Jefferson, Orleans, Plaquemines, St. Bernard and St. Charles in Louisiana; the U.S. Virgin Islands; and Puerto Rico and Guam. About 2 million cartons of grapefruit and oranges valued at $11 million were treated with EDB in the 1981-83 period. About 15 to 20 percent of

the total citrus production in Texas have been fumigated in the past years (12). Citrus production in Texas was severely curtailed after the damaging freeze that occurred in late 1983.

The major export markets for Texas citrus are Europe, Japan, and Canada. Although these countries do not require treatment for A. ludens, California requires EDB fumigation and the majority of Texas citrus exported to Japan transits California. If EDB were lost, alternative transit routes would have to be found and developed since they are not now available. If all markets requiring EDB were lost, it would place the citrus industry at a disadvantage in trying to compete with producers in other areas for markets that do not require fumigation. Almost no citrus was shipped in 1985 because of the recent freeze in the Rio Grande Valley. Alternative controls similar to those applicable to Florida would apply.

Chilean Fruit

Large quantities of deciduous fruits totaling an average of 221,000,000 pounds each year between 1983 and 1985 are imported into the U.S. from Chile. Grapes comprise 80 percent of the total quantity shipped and other fruits include apricots, cherries, nectarines, peaches, pears, and plums. This activity has been increasing on an annual basis and is an important one economically. All treatments are conducted using MB. No registered or approved alternative control method presently exists. Fruit irradiation may prove acceptable several years from now.

Khapra Beetle Cargo

In order to prevent the entry of KB (*Trogoderma granarium* Everts), certain articles are required to be fumigated with MB (7 CFR 319.75-Khapra Beetle). Articles listed below are covered by these regulations:

Brassware and wooden screens.

Whole red chilies, or peppers (*Capsicum* spp.) in jute or burlap bags.

Cumin seeds (*Capsicum* spp.) in jute or burlap or better.

Goatskins, lambskins, sheepskins (except tanned, blue-chromed, pickeled in mineral acid, or salted and moist).

Seeds of Cucurbitaceae in shipments of more than two ounces if not for propagation.

Used burlap or jute bagging not containing cargo.

Used burlap or jute bagging containing flour or finely ground oil meals.

Baled cotton lint, linters, or waste; or cotton piece goods with used burlap as wrapper or packing.

Used burlap or jute bagging used as packing and wrapping for cargo other than above.

Plant gums shipped as bulk cargo, including acacia, guar, arabic, locust, and tragacanth gums.

And if the article is from: Afghanistan, Algeria, Bangladesh, Burma, Cyprus, Egypt, India, Iran, Iraq, Israel, Libya, Mali, Mauritania, Morocco, Niger, Nigeria, Pakistan, Saudi Arabia, Senegal, Sri Lanka, Sudan, Syria, Tunisia, Turkey, or Upper Volta.

Most KB fumigations are conducted in temporary polyethylene enclosures. An average of 827 treatments have been conducted each year for the past two years. Because of the variety of commodity treated ranging from individual cartons of brassware to barges of bulk gums, no meaningful dollar value is estimable. Each temporary enclosure treatment costs about $400 with entire warehouse fumigations averaging $10,000.

No practical alternatice to MB currently exists. Phosphine fumigation has been tested experimentally but the length of time necessary, five to seven days, at high concentration levels has prevented its application. Although totally restructuring wrapping, packing, and shipping practices may be theoretically possible, most of the restricted products originate in developing countries where such technology does not presently exist.

Mangos - Haiti and Mexico

Haiti and Mexico, with smaller amounts from Brazil, and the Dominican Republic, exported mangos to the United States until September 1, 1985. The export of this commodity is an important economic activity in these developing countries, although the quantity exported (7,000 tons from Haiti and 29,000 tons from Mexico in 1985) have not been large in comparsion to the other regulated commodities. No practical alternative controls exist and shipments have temporarily ceased.

Vapor heat treatments are approved by APHIS for mangos but the only variety known to be tolerant is no longer shipped. There are no vapor heat treatment

facilities in existence and no current plans to construct them. Irradiation treatment could eventually be implemented in the future as an alternative. However, it is not presently approved by FDA and no information exists on fruit tolerance levels and the liklihood of building expensive irradiation facitilies. ARS is currently conducting research on hot water dips. If successful, this alternative could be available in about one year.

Citrus - Mexico

Large quantities of citrus have been imported from Mexico for the domestic market, an annual average of 1,250,000 cartons (42.5 pound carton) in the period 1981-84. This trade has come to a virtual standstill since the termination of EDB usage. These trade impacts have worsened the economic situation in Mexico and to some extent harmed the political position and image of the United States in Mexico.

No satisfactory alternative control exists. MB fumigation was approved based on available research but it has not proven entirely practical, especially for oranges. Problems developed regarding tolerance of the fruit to the treatment, especially with oranges, and survival of insects due to large numbers of mature larvae present in some instances. Due to recent freezes in northern Mexico, citrus fruits were harvested in more southerly locations that are subject to heavier insect infestation levels. The MB treatment schedules were developed based on probit 9 survival in laboratory-infested fruit. Unacceptable pest survival rates resulting from MB fumigations on naturally infested fruits suspended its use in the 1984-85 season.

Expert opinion indicates that treatment of many varieties of tangerines with MB may be practical, MB treatments on grapefruit may be marginally successful, and MB treatments of oranges may be impossible with many varieties. The use of irradiation, phosphine fumigation, the fly-free zone concept, eradication, vapor heat, and cold treatments are subject to limitations as in other citrus crop applications and do not appear as practical alternatives.

PESTICIDE REGULATORY SCENARIO: CANCELLATION OF ALL FUMIGANTS

Fumigants are toxic chemicals which can leave residues on treated products. Because of public health concerns regarding the risks of workers' exposure to these chemicals and the consumption of fumigated products, the use of fumigants in domestic and foreign quarantine is subject to pesticide regulatory actions. In this report, we examine the economic impacts on domestic producers and consumers caused by the complete cancellation of fumigant uses (EDB and MB) in quarantine control pprograms. The cancellation of only EDB assuming that MB is still available for use is not considered because in the assessment of experts MB is not yet a commercially feasible control alternative for all regulated commodities.

The analysis centers on changes in the costs of control, quantity of shipments of regulated commodities, and other relevant factors due to the adoption of alternative control technologies. This report discusses only the incremental impacts of hypothetical pesticide regulatory action on quarantine programs. Economic impacts are estimated only for domestic producers and consumers of selected agricultural commodities.

KEY ASSUMPTIONS AND PROCEDURES FOR REGUALTORY IMPACT ANALYSIS

The crucial step in this analysis is specifying exactly how the cancellation of fumigant uses and subsequent adoption of alternative control technologies would affect domestic producers and consumers. There is no clear and simple approach to evaluate the economic impacts resulting from policy-induced or technological changes due to suspensions in the agricultural use of chemicals. Many factors concerning the movement or trade of regulated fresh commodities are relevant such as, the quantity of shipments, the nature of trade markets, market shares and commodity prices, the kinds and costs of alternative quarantine control measures, producer and consumer responses, and administrative actions.

The economic implications are based on a number of assumptions and limited to a selected group of regulated commodities. Assumed in this analysis are annual average conditions on current fumigant use, quantity of shipments of regulated commodity groups, current price relationships, and other exogenous variables. The quantities of regulated commodities subject to mandatory quarantine control treatments are assumed constant in order to simplify the analysis. Economic impacts to consumers of khapra beetle commodities are excluded because accurate information is not available on the kinds of treated commodities, prices, demand schedules, and alternative control technologies.

Alternative controls include those technologies that are presently available for use or those nearing development in the near future. There is a high degree of uncertainty associated with their future development, acceptance by quarantine officials, and effects on the quality and quantity of shipments of regulated

commodities. This is because most alternative control technologies are neither presently implemented nor completely acceptable for immediate use. This analysis assumes that adopted alternative controls are equally effective and acceptable as conventional fumigant controls to aviod further specualtion. In other words, the risk of new pest introduction after alternative control technology is implemented remains unchanged. Control technologies that were described as options in the future were excluded as alternative controls.

The analysis centers on the changes in the private cost of quarantine control and the effect alternative controls upon the commodity treated in comparsion to conventional fumigant treatments. Data on current fumigant uses and alternative control technologies were a joint effort of the Quarantine and Regulatory Fumigant panel. Therefore, this evaluation is dependent upon subjective estimates provided by experts and other sources. Although the information was collected in a systematic way, this evaluation should be viewed as indicative of the relative magnitude and direction of economic impacts due to the presence of uncertainties and the need for assumptions.

A partial budgeting technique is utilized to estimate the relative magnitude of impacts. This technique allows the easy calculation of short-run impacts in a static sense. First, each alternative control technology is evaluated under two alternative cases for each regulated commodity: Case I, the adoption of alternative controls do not significantly affect the quality or quantity of shipments of regulated commodities; and Case II, changes in the quality of treated commodities due to adoption of alternative treatments represent decreases in the final quantity of shipments reaching market destinations. These two cases are incorporated into the analysis because of the currently

anticipated effects of alternative on technologies on the quality of fresh fruits undergoing treatment as previously discussed in the report.

Case I involves no change in the quality of treated fresh fruits and changes in quarantine control costs become the sole parameter of economic impacts. Assuming constant average prices and demand schedules for the regulated commodities, the gross revenue of producers remains unchanged and a direct measure of the economic impact can be computed by the changes in the net revenues due to changes in control costs. It is implicitly assumed in this study that producers of the exporting region are price-takers, therefore consumers in the exporting and importing regions are basically not affected.

In Case II, alternative control technologies affect the quality of regulated commodity shipments based on current results of commercial tests and expert assessments. Changes in fresh fruit quality are estimated as levels of skin and internal injuries, fruit decay, and unacceptable taste. These quality changes in turn affect the final quantity of regulated commodities that are marketed after undergoing alternative control treatments. Changes in the quantity of treated commodities reaching final market destination in turn affect market prices. The magnitude of market price changes are determined from the slope of the demand curve estimated for each regulated commodity in their respective market. A statistical demand model, which is linear in logarithms, is estimated for each selected commodity because it yields constant elasticities. 3/

3/Detailed data, data sources, and estimation procedures and results may be obtained from the panel on request.

Estimates of the price elasticity of demand, defined as the proportional change in the consumption of a good divided by the proportional change in its price, are used to determine the relative impacts on producers and consumers.

This case also entails a more difficult and speculative analysis because of the relaxation in the supply assumption and the absence of adequate information on the true nature of demand and supply responses to alternative controls. It is assumed that changes in the final quantity supplied and demanded, movements along the demand function of each regulated commodity in a particular market, result in a new equilibrium condition where new market price and quantity are determined. Increases in commodity supply are likely with the adoption of alternative controls and trade movements, but these are omitted by assumption.

Two alternative control adoption outcomes have been developed by experts in the event of a complete ban on the use of fumigants for domestic and foreign quarantine purposes. These are based on the current availability and commercial feasibility of alternative controls and are specified for the immediate (0-1 year) and longer (1-3 years) terms (Table 1). Each row indicates the alternative controls that are available for each commodity group and each column indicates the mix of alternative controls resulting from this regulatory action scenario. Aggregate impacts for each case and outcome are computed by summing partial impacts estimated for each selected commodity and adopted control technology.

Table 1. Cancellation of all fumigants: outcomes of immediate and longer term adoption of alternative control technologies

Market Destination Commodity Group	Immediate adoption (0-1 year)		Longer term adoption (1-3 years)	
	Outcome 1	Outcome 2	Outcome 1	Outcome 2
U.S.:				
Citrus	Pest-free zone	Vapor heat treatment	Irradiation	Pest-free zone
Chilean fruits	None	None	Irradiation	Irradiation
Caribbean mangos	Hot water treatment	Hot water treatment	Irradiation	Irradiation
Japan:				
Florida grapefruit	Cold treatment	Cold treatment	Irradiation	Pest-free zone
Hawaii papayas	Hot water treatment	Vapor heat treatment	Irradiation	Eradication
Washington cherries	None	None	Irradiation	Irradiation

The immediate substitution of current fumigant control practices refers to those outcomes in which an approved alternative technology is presently feasible. Adoption in the longer term refers to the prospective development and commercial application of an alternative control, which will be an accelerated process in the event of a complete ban on fumigant uses. An immediate control substitute for MB treatments on Chilean fruits and Washington cherries is not currently available. This means that shipments of these commodities will cease temporarily until irradiation or another control is developed in the near future. Shipments of these commodities will have to be routed or marketed elsewhere.

BASELINE ESTIMATES

The current use of fumigants on normalized quantities (three to four-year averages) of selected regulated commodities is the initial set of conditions to which the probable adoption of alternative control technologies is compared (Table 2). Selected regulated commodities are classed as destined for domestic or export markets by crop and State or country of origin. The quantity of commodities is given in boxes of fresh fruit.

The total quantity of treated commodities is estimated at 34.6 million boxes of fresh fruit and 161,134 units of KB cargo per year. The total value of fumigated fresh fruits is approxiamtely $349.7 million. The total quantity of fumigant used on these commodities is estimated at 151,765 pounds. Total fumigant costs are estimated at about $3.96 million, of which $0.53 million are charged to domestic producers.

Table 2. Fumigant uses, baseline quantities, selected U.S. commodities

Market destination selected commodity	Origin	Commodity treated		Fumigant		Cost of control	
		Total quantity	Estimated total value	Material	Total use	Per unit	Total
		Boxes	Dollars		Pounds		Dollars
U.S. markets:							
Fresh citrus (1981-84):							
Oranges	Mexico	194,400	1,269,432	EDB	2,110	0.0700	13,608
		21,600	141,048	MB	100	0.0800	1,728
	Texas	3,500	25,165	EDB	28	0.0100	350
	Subtotal	219,500	1,435,645		2,238		15,686
Tangerines	Mexico	472,500	4,432,050	EDB	5,130	0.0700	33,075
		52,500	492,450	MB	240	0.1000	4,200
	Subtotal	525,000	4,924,500		5,370		37,275
Grapefruit	Mexico	116,100	493,425	EDB	1,260	0.0700	8,127
		12,900	54,825	MB	60	0.0800	1,032
	Texas	1,980,000	10,850,400	EDB	15,840	0.0100	198,000
	Subtotal	2,109,000	11,398,650		17,160		207,159
Fresh deciduous (1983-85)a/	Chile	19,450,225	271,815,715	MB	61,213	0.1500	2,917,534
Mangos (1981-84)	Haiti Mexico	6,534,089	21,366,471	EDB	2,700	0.0184	120,227
KB cargo (1983-84) b/	c/	161,134 d/	e/	MB	55,712	2.0529	330,798
U.S. exports (Japan):							
Grapefruit (1981-84)	Florida	4,852,270	33,189,527	EDB	3,882	0.0600	291,136
	Texas	20,000	109,600	EDB	160	0.1000	2,000
	Subtotal	4,872,270	33,299,127		4,042		293,136
Cherries (1982-85)	Washington	191,288	3,997,919	MB	1,730	0.1500	28,693
Papayas (1981-84)	Hawaii	704,840	1,455,495	EDB	1,600	0.0160	11,277
Baseline totals		34,767,346	349,693,522 f/		151,765		3,961,785

a/ Includes grapes, nectarines, pears, plums, peaches, cherries, and apricots.
b/ Many agricultural and non-agricultural commodities which serve as carriers of khapra beetles.
c/ Several Southeast Asian and African countries.
d/ From individual cartons of brassware to barges of bulk gums.
e/ Not estimated.
f/ Excludes value of KB cargo.

FUMIGANT AND ALTERNATIVE CONTROL COST COMPARISON

The cost of EDB treatment has averaged $1.60 per 1,000 pounds of product for several years. MB fumigation costs are estimated to be $0.15 per box of fruit or $400.00 per fumigation for non-agricultural products. Costs for the double hot water dip are estimated to be approximately $6.25 per 1,000 pounds of fruit. Commercial rates for cold treatment are currently $6.25 per 1,000 pounds of fruit, applied ashore or on board the vessel while in transit. There are presently no vapor heat facilities. It is assumed that vapor heat treatment costs would be similar to cold treatment of $6.25 per 1,000 pounds of fruit. Due to the location and energy requirements of possible facilities, actual costs could be greater. The cost of irradiation treatments to domestic producers vary by crop and estimated as follows, $0.42 per box of Florida grapefruit and Hawaiin papayas, $0.45 per box of Texas citrus, and $0.50 per box of Washington cherries.

Table 3 shows changes in the cost of alternative controls as compared to current fumigant treatment costs per box of fresh fruit. These costs represent only the changes in private quarantine costs to domestic producers when the current fumigant control is effectively replaced by an alternative control technology. Increases in control costs range from 5 to 69 cents per unit treated and are greatest for cold treatments on citrus, vapor heat treatments on citrus and papayas, and irradiation technology on papayas and cherries. Decreases in control costs are estimated after pest-free zones and pest eradication programs are successfully implemented. However, the producer share of implementing these programs is not included because this information is not presently available.

Table 3. Changes in costs of alternative quarantine control per unit in comparison to current fumigant controls

Alternative control	Treated commodities			
	Texas citrus	Florida grapefruit	Hawaii papayas	Washington cherries
	- - - - - - - -Dollars- - - - - -			
Methyl bromide	0.060	0.240	0.134 a/	n/a
Cold treatment	0.400	0.690	n/a	n/a
Pest-free zone or eradication b/	-0.100	-0.060	-0.016	n/a
Irradiation	0.350	0.350	0.400	0.350
Vapor heat	0.400	0.690	0.400	n/a
Hot water	n/a	n/a	0.047	n/a

n/a Indicates that control option is not a feasible alternative.
a/ Combination of MB fumigation and a single hot water dip treatment.
b/ Does not include producer share of cost of implementing programs.

It is anticipated that the implementation of these programs would entail a fee charged to private producers of particular products and added public costs for program operations and maintenance.

ALTERNATIVE CONTROL ADOPTION IMPACTS

Under Case I, assuming that no changes in the quality or quantity of the treated commodity occurs, estimates of annual changes in the net revenue of domestic producers for each presently available chemical and nonchemical alternative control option are shown in Table 4. In general, the adoption of an alternative option other than an established pest-free zone or pest eradication program represent a negative impact to producers due to substantial increases in the estimated cost per unit of quarantine control.

Cost of control increases represent losses in the net revenue of producers. Florida producers would suffer the greatest losses because of the quantity of grapefruit requiring quarantine treatment for shipment to Japan. The successful establishment of pest-free zones and implementation of pest eradication programs would provide benefits to produers instead. Excluding the private and public costs of implementing these programs, producers gain between 1.6 and 10 cents per treated box. By assumption, impacts to domestic consumers are not estimated in this particular case, as the increase in control costs will be borne entirely by domestic and foreign producers.

Annual economic impacts when the final quantity of treated commodities reaching market destinations is expected to change due to alternative control treatments

Table 4. Case I: Annual changes in producer net revenue assuming that the quantit of treated commodities remains constant, by commodity and alternative control technologies

Alternative control	Treated commodities			
	Texas citrus	Florida grapefruit	Hawaii papayas	Washington cherries
	-Dollars-			
Methyl bromide	-120,210	-1,164,545	-94,449 a/	n/a
Cold treatment	-801,400	-3,348,066	n/a	n/a
Pest-free zone or eradication b/	200,350	291,136	11,277	n/a
Irradiation	-701,225	-1,698,295	-281,936	-66,951
Vapor weat	-801,400	-3,348,066	-281,936	n/a
Hot water	n/a	n/a	-33,127	n/a

n/a Indicates that control option is not a feasible alternative.
a/ Combination of MB fumigation and a single hot water dip treatment.
b/ Does not include producer share of cost of implementing programs.

are shown in Table 5 by control technology and commodity category. Expert estimated changes in the supply of regulated crops represent best approximations of the probable magnitudes of change. For those crops where the magnitude of change was difficult to estimate, decreases in the final supply of commodities were simulated at the 10 percent level.

AGGREGATE ECONOMIC IMPACTS OF REGULATORY SCENARIO

An overview of the benefits of fumigant use to specific areas and crops has been presented earlier in this report. In this section, aggregate estimates of the economic impacts to domestic producers and consumers in the absence of fumigant use are quantified. These estimats are based on the adoption of alternative control technologies for the immediate and longer terms (see also Table 1). These annual estimates are shown in Table 6 for each previously specified case and outcome.

Assuming that the supply of regulated commodities remains constant, the immediate impact is an annual loss in the net revenue of domestic producers. This annual loss is estimated at between 3.2 and 4.4 million dollars for two adoption outcomes. The greatest proportion of this aggregate loss is borne by Florida grapefruit producers due to a shift to cold treatment control. The direction of the economic impact to domestic producers in the longer term varies according to the adoption outcome. If irradiation technology is the sole option adopted (longer term, case I, outcome 1), the impact is an annual loss in producer net revenue of 2.7 million dollars due to cost increases. In commodity categories where pest-free zones or eradication programs could be implemented

Table 5. Case II: Annual economic impacts to producers and consumers, expert estimated changes in the final quantity of treated fruits reaching market destination, by alternative control option and commodity category

Alternative control market destination crop	Changes in total supply	Impact to consumers		Impact to producers			
		Change in price per unit	Total expend-itures	Change in cost of control per unit	Change in total cost of control	Change in gross revenue	Impact on net revenue
	--Boxes--	----------	----------	----------	-Dollars-	----------	
MB treatment							
U.S. market:							
Oranges	-19,790	0.004	35,402	0.060	210	155,941	155,731
Grapefruit	-209,610	0.088	764,948	0.060	118,800	715,076	596,276
Japan:							
Grapefruit	-487,227	n/a	n/a	0.240	1,165,745	-2,477,062	-3,646,407
Cold treatment							
U.S. market:							
Oranges	-64,870	0.013	110,858	0.40	1,400	513,794	512,394
Tangerines	-157,500	1.025	2,586,134	n/a	n/a	2,769,793	2,769,793
Grapefruit	-78,300	0.033	292,829	0.40	792,000	460,491	-331,509
Japan:							
Grapefruit	-485,627	n/a	n/a	0.69	3,361,866	-2,477,062	-5,838,928

--Continued

Table 5. --Continued

Alternative control market destination crop	Changes in total supply	Impact to consumers		Impact to producers			
		Change in price per unit	Total expenditures	Change in cost of control per unit	Change in total cost of control	Change in gross revenue	Impact on net revenue
	Boxes	Dollars					
Pest-free zone or eradication							
U.S. market:							
Oranges	-129,600	0.027	262,047	-0.10	-350	1,068,063	1,068,413
Tangerines	-315,000	2.216	5,481,335	n/a	n/a	10,796,950	10,796,950
Grapefruit	-77,400	0.032	276,031	-0.10	-198,000	655,164	853,164
Irradiation							
U.S. market:							
Oranges	-21,950	0.005	62,472	0.35	1,225	195,499	194,274
Tangerines	-52,500	0.325	830,097	n/a	n/a	1,583,488	1,583,488
Grapefruit	-210,900	0.089	779,422	0.35	693,000	735,352	42,352
Chilean fruits:							
Apricots	-463	5.026	36,183	n/a	n/a	n/a	n/a
Cherries	-4,121	2.493	65,490	n/a	n/a	n/a	n/a
Grapes	-1,630,089	0.820	-10,281,359	n/a	n/a	n/a	n/a

--Continued

Table 5. --Continued

Alternative control market destination crop	Changes in total supply	Impact to comsumers		Impact to producers			
		Change in price per unit	Total expend-itures	Change in cost of control per unit	Change in total cost of control	Change in gross revenue	Impact on net revenue
	-Boxes-	-Dollars-					
Chilean fruits:							
Nectarines	-156,516	4.099	4,828,045	n/a	n/a	n/a	n/a
Peaches	-30,355	1.376	223,612	n/a	n/a	n/a	n/a
Pears	-68,873	1.956	2,188,472	n/a	n/a	n/a	n/a
Plums	-54,605	2.017	678,602	n/a	n/a	n/a	n/a
Mangos	-653,409	0.831	2,520,530	n/a	n/a	1,058,170	1,058,170
Japan:							
Grapefruit	-487,227	n/a	n/a	0.35	1,705,295	-2,477,062	-4,182,357
Cherries	-19,129	n/a	n/a	0.35	66,951	-186,142	-253,093
Papayas	-70,484	n/a	n/a	0.40	281,936	-272,280	-554,216
Vapor heat							
U.S. market:							
Oranges	-64,870	0.013	110,858	0.40	1,400	513,794	512,394
Tangerines	-157,500	1.025	2,586,134	0.00	0	2,769,793	2,769,793
Grapefruit	-78,300	0.033	292,829	0.40	792,000	460,491	-331,509

Table 5. --Continued

Alternative control market destination crop	Changes in total supply	Impact to consumers		Impact to producers			
		Change in price per unit	Total expend-itures	Change in cost of control per unit	Change in total cost of control	Change in gross revenue	Impact on net revenue
	-Boxes-	-Dollars-					
Japan: Grapefruit	-485,627	n/a	n/a	0.69	3,361,866	-2,477,062	-5,838,928
Chilean fruits: Papayas	-70,484	n/a	n/a	0.40	281,936	-272,280	-554,216
Hot water							
U.S. market: Mangos	-653,409	0.831	2,520,530	n/a	n/a	1,058,170	1,058,170
Japan: Papayas	-70,484	n/a	n/a	0.134	94,449	-272,280	-366,729

n/a Indicates no impact is estimated.

Table 6. Annual aggregate economic impacts to domestic producers and consumers due to a complete fumigant cancellation in quarantine programs by outcome in the immediate and longer terms a/

Case	Impact to:	Immediate		Longer	
		Outcome 1	Outcome 2	Outcome 1	Outcome 2
		Million dollars			
I.	Constant supply				
	Producers	-3.2	-4.4	-2.7	+0.4
II.	Supply decreases				
	Producers	+8.3	-2.4	-2.1	+13.8
	Consumers	+8.5	+5.5	+4.5	+8.8

a/ Economic impacts are estimated as changes in the net revenue of domestic producers and changes in consumer expenditures for selected regulated commodities.

(longer term, case I, outcome 2), the estimated impact is a gain in producer revenue of $0.4 million excluding the producer share of program costs.

If the final supply reaching market destination decreases due to changes in fruit quality and accounting for price effects (case II), the maximum loss estimated for domestic producers is $2.4 million annually under outcome 2 in the immediate term. Longer term impacts to domestic producers are estimated as a range between an annual loss of $2.1 million when irradiation is the sole control adopted (outcome 1) and a gain in revenue of $13.8 million when pest-free zones or eradication programs are implemented (outcome 2).

There is a wide disparity in the range and direction in which aggregate impacts are specified for each outcome. This disparity is indicative of varying degrees of impacts to producers (see also Table 5). For example, Florida producers face high loss in net revenue in all but one outcome with the adopted technologies. Domestic mangos and tangerine producers, who are not subject to mandatory quarantine treatments in this analysis, would gain if the supply of their crops that is exported into the domestic market were to decrease. This is due to the presence of windfall gains accruing to them because of increases in market prices. These windfall gains are the main reason for the anticipated gains in producer revenue.

Domestic consumers would be unaffected by changes in quarantine control costs when the quality and quantity of regulated commodities is not subject to change. Assuming otherwise, domestic consumers will be impacted by increases in their total expenditure for regulated commodities. An annual range of about $5.5 and

$8.5 million for the immediate term and $4.5 to $8.8 million in the longer term in increased expenditures is estimated depending on the adopted control technology.

LIMITATIONS OF ECONOMIC IMPACT ANALYSIS

Several limitations apply in the examination of the hypothetical pesticide regulatory scenario and the estimation of economic impacts because of the methodology and assumptions used in the analysis. First, this analysis is based on a short run, static analysis of a dynamic and uncertain system. The technique employed in this analysis provides an approximation of the economic impacts in the absence of fumigants and impacts should not be viewed as absolute magnitudes of the expected effects. This analysis relied extensively upon expert opinion on the marginal changes in quarantine costs and quantities of selected regulated commodities reaching final market destination. To the extent that estimates in the cost of control, producer and consumer responses, final supplies, and other omitted market factors change due to the adoption of alternative controls, estimated impacts will require modification.

The analysis is based on estimates of limited market impacts and excludes other relevant factors needed for decision making. Among these factors are those that cannot be measured quantitatively and those for which relevant data is either not available or difficult to assemble. Examples of these are added private and public costs to comply with post-fumigant quarantine regulations, changes in environmental quality, human exposure to chemical and non-chemical alternatives, productin practices and commodity shipping in the countries exporting regulated commodities to the U.S. market, and long run implications.

Economic impacts are estimated for domestic producers and consumers, but implications for foreign producers and consumers have not been explored. Nor have interactions among commodity markets been taken into account. The trade market of regulated commodities is dynamic and assuming that the baseline estimates remain unchanged limit the extent of the analysis.

CONCLUDING REMARKS AND RESEARCH NEEDS

The use of fumigants is an important component of effective domestic and foreign quarantine programs. EDB and MB are presently the only authorized fumigants used on selected regulated commodities. These chemicals could be cancelled by EPA's regulatory authority because of public health concerns.

This report focused on the current use of fumigants and the benefits and costs of their withdrawal as a control measure. There are alternative control technologies to conventional fumigant use, however the extent in which these technologies could be implemented immediately following a complete ban on fumigant use is subject to uncertainty. A partial budgeting technique accounting for market factors utilizes expert estimated changes in marginal economic variables to quantify impacts in the immediate and near future terms. Crucial to this analysis are changes in per unit cost of quaratine control in the absence of fumigants and effects on the quantity and quality of treated commodities when alternative controls are adopted.

In the event of a complete ban in the use of quarantine fumigants, domestic producers will be generally negatively affected due to cost increases unless

pest-free zones or eradication programs can be implemented and market prices change. The use of alternative nonchemical control options may have an effect on the quality of treated commodities. Changes in fruit quality can be translated into decreases in the final supply of regulated commodities reaching market destination. Under these conditions, domestic producers would face losses in net revenue when cost increases are not offset by windfall gains in gross revenues due to market price increases.

Domestic consumers will not be affected if the quantity and quality of treated commodity shipments remains unchanged because the entire impact of cost changes is borne by domestic and foreign producers. If supply decreases, consumers will increase annual total expenditures for the treated commodities.

There is a need to effectively develop alternatives to conventional fumigant use in quarantine programs. Alternative control methods will require the approval of quarantine officials and commercial acceptance by producers and consumers. Basic research is needed for an environmentally sound control method to replace EDB and MB use on citrus, mango, papayas, cherries, KB cargo, and Chilean fruit. Research is also indicated on irradiation and nonchemical methods, such as heat or cold treatments, for the same commodities. Research to fill these needs is in progress or planned by ARS at the following locations: for mango and citrus treatment alternatives at Miami, Florida and Weslaco, Texas: for papaya and other Trifly hosts at Hilo, Hawaii: and for irradiation data for these commodities at the same respective locations.

SUMMARY

The movement of several agricultural and non-agricultural commodities is regulated by State, Federal, and foreign quarantines. Quarantine measures are legally mandated and include exclusion, inspection and chemical treatments. Two fumigants are used extensively to comply with domestic and foreign quarantine programs, ethylene dibromide and methyl bromide. Both materials have proven effective and insure that a variety of fresh fruits, vegetables, and other commodities are free from any undetected pest activity.

Ethylene dibromide has been used effectively for treating fresh products originating in areas infested by tropical fruit flies. The only presently authorized uses of this chemical as a post-harvest fumigant are on citrus and papayas to be exported from the United States, primarily to Japan. Methyl bromide has been used extensively to treat cherries for export, imported Chilean fruits, and khapra beetle cargo.

There are no chemical alternatives to the fumigants presently used for quarantine purposes. Alternative nonchemical control technologies include the application of vapor heat, hot water dip, low temperature, and irradiation treatments. Areawide programs, such as established pest-free zones or pest eradication, are also considered as alternative control methods. Alternative controls have not effictively replaced the use of conventional fumigants in most cases. There is a need for increased research to develop effective and environmentally sound quarantine control measures. An effective alternative to the use of fumigants must be cost effective, commercially adopted by producers and consumers of regulated products, and accepted by quarantine officials.

Because of public health concerns, the use of fumigants is subject to pesticide regulatory actions. Fumigant residue levels on treated commodities cannot exceed safe limits imposed by EPA. Fumigant worker exposure levels must comply with OSHA regulations.

In the event of a complete ban on the use of fumigants for quarantine purposes, the aggregate economic impact to domestic producers of the selected commodities covered in this report varies according to the commodity, market destination, and adopted alternative control. Assuming that the quantity of the selected regulated commodities remains unchanged, the annual losses in producer net revenues are estimated in the range of $3.2 to $4.4 million in the longer term due to increases in control costs. Producers may realize gains only if effective pest-free zones or eradication programs on certain areas and crops eliminate the need for mandatory pest treatments under the same quantity assumpti

Assuming that the quantity of the selected regulated commodities using alternative treatments decrease due to changes in fruit quality, the impact to producers will depend on whether changes in their gross revenues offset the increases in control costs. Under these conditions, the annual maximum loss estimated for domestic producers is between $2.1 and $2.4 million. Alternatively, producers may gain an aggregated $8.3 to $13.8 million. The wide disparity is indicative of the several combinations for alternative control adoption and the windfall effects of commodity price increases due to quantity decreases.

Domestic consumers will increase their expenditures for the selected regulated commodities in the range of $4.5 to $8.8 million if the quantity treated decreases.

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SOIL FUMIGANTS

BIOLOGIC AND ECONOMIC ASSESSMENT OF SOIL FUMIGANTS

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THE BIOLOGIC AND ECONOMIC ASSESSMENT OF SOIL FUMIGANTS

INTRODUCTION

This is an evaluation of the impacts of the loss of one or more preplant soil fumigants upon six representative crops, citrus, cotton, potatoes, tobacco, tomatoes, and forest nurseries. Assessments of use/loss of soil fumigants, the use of alternative pesticides and cultural practices, and estimates of differences in efficacy and practicality of alternatives, as expressed by yields and related production costs, have been made as they affect the control of plant-parasitic nematodes, plant diseases, weeds, and insects, in agricultural soils. The biological evaluations, basically an interrelated collection of perspectives and estimates based on experience, were made by a panel of 15 Federal and State scientists, representing the four disciplines, from the Agricultural Research Service and the U.S. Forest Service, United States Department of Agriculture, Cooperative Extension Service, State Agricultural Experiment Stations, and agricultural economists from the Economics Research Service, United States Department of Agriculture, who prepared the economic evaluation.

BIOLOGIC ASSESSMENT

BACKGROUND

Among the most urgent problems that confront commercial growers is the continuing need to control crop-attacking nematodes, plant diseases, weeds, and insects, even as chemical control capabilities diminish because of cancelled pesticide registrations. Losses from these pests account for an estimated 30 percent of potential food supplies (10, 17). At current price levels, crop losses due to these pests are estimated to total approximately \$35 billion yearly, including \$10+ billion estimated as being due to insects, \$10+ billion weeds, \$7+ billion nematodes, and \$7+ billion plant diseases. The use of pesticides has prevented even greater losses, as documented in this assessment.

The most efficient means of controlling nematodes and soilborne diseases, and to a lesser extent, weeds and insects, now and in the foreseeable future, is by the use of various preplant soil fumigants. Due to their volatile nature, fumigants must be injected in the soil, and/or applied under seal, or by irrigation. Once in the soil, which must be in good tilth and with sufficient moisture, the fumigant diffuses into available water films, moving away from points of application in predictable lateral and vertical patterns. The result, when the fumigant is applied at proper concentrations with proper spacing, is permeation of the soil. Under ideal application conditions, treatments to control nematodes and disease organisms may be 85 to 90 percent effective, sufficient to provide nematode control and in certain instances, control of disease organisms, for one growing season. Weed and insect control is less dependent on the use of soil fumigants.

Currently registered soil fumigants cannot be used in the soils on and around plant roots because they are toxic to plant tissues. However, they are relatively more efficient and their soil distribution patterns are more uniform, than nonvolatile pesticides. Nonvolatile or nonfumigant compounds such as the several registered organophosphates and carbamates, which may be used in soils, are less effective than the fumigants because they do not move under their own power as do fumigants. They must be incorporated in or drenched into the soil to the depths at which control is required. This may often be a difficult or an impossible task, especially when these compounds must be applied to deeper soil areas with little or no damage to the roots of established plants.

The greater efficacy of soil fumigants is not an unalloyed blessing. Soil and groundwater surveys and evaluations for carcinogenicity since 1977 identified two of the most widely used fumigants, DBCP (1,2-dibromo-3-chloropropane), and EDB (ethylene dibromide), as groundwater pollutants and as being associated with sterility and carcinogenicity. Their registrations were cancelled in 1981-1984, and 1983, respectively; they are no longer legally available for use as soil fumigants in the United States (8, 9).

Several other soil fumigants, methyl bromide, 1,3-D, and chloropicrin, which have been increasingly used as alternatives for the cancelled compounds, may also be implicated in groundwater pollution and may become subjects of

cancellation proceedings. In addition, three of the nonvolatile pesticides, aldicarb, carbofuran, and oxamyl have been identified as contaminants in groundwater.

The need for pest control in the soil mass brings additional problems into focus. These are shared by the soil fumigants and the nonvolatile pesticides.

The soil mass is one of the least understood and most difficult to manage aspects of the environment. It frequently stands as a significant barrier to practical pest control, preventing many pesticides from penetrating to targets effectively, or degrading or inactivating them before they reach sites of activity in concentrations high enough to provide significant control. At best, control of soil-inhabiting pests under field conditions is temporary. The soil is a complex of interacting biological and physical factors that include variations in moisture and pH microgradients which tend to affect the activity of pesticides. As a result, the best control efforts in the field fall short of eradication. The fractions of pest populations that survive soil treatments increase over time, requiring that the soil be treated at regular intervals, usually but not restricted to, once per growing season.

Techniques for the placement of pesticides in the soil require improvement. At present, they are at a level of efficacy that requires the application of overdoses to reach practical control goals. Even so, many pesticides, especially the soil fumigants, show intrinsically inadequate levels of residual activity, not long enough for maximum efficiency but, at the same time, sufficient to cause environmental contamination.

Thus, capabilities for the control of soil-inhabiting pests are inadequate, and they may be reduced further by the need to cancel registrations of pesticides that contaminate the environment. Continuing needs for more effective fumigant pesticides, including compounds that are practical for use on and around living plants, as well as for use in the soil mass, must be met to make soil pest control possible without sacrificing groundwater quality.

Fumigants are innately more effective pest control agents in the soil than the nonvolatile pesticides. Almost without exception, they contribute to the

improvement of agricultural soils when they are applied properly. They make possible the production of various commercial crops that could not otherwise be grown economically. These include strawberries, pineapples, and subtropical and tropical crops in general. Soil fumigation is the most efficient method for fitting soils for the planting of perennial crops and helps to assure early vigor of seedlings and more productive yields. In addition, soil fumigants have an integral role in meeting the requirements of regulatory programs. Soil fumigant capabilities need to be maintained.

Assumptions and Methodology

Studies of the effects of suspensions or cancellations of agricultural pesticides usually deal with single compounds. In this study, the Soil Fumigant Assessment Panel has evaluated the impacts of the loss of the four registered soil fumigants, and the use of alternative nonfumigant pesticides and nonchemical means of control if one or more of the soil fumigants do become unavailable due to suspension or cancellation. As noted above, several of these nonfumigant or nonvolatile compounds may also be subject to suspension or cancellation.

The soil fumigants currently registered for use in agricultural soils are:

1. methyl bromide, or bromoethane (MBr).

2. 1,3-D, or 1,3-dichloropropene.

3. chloropicrin, or trichloronitromethane.

4. metam, or metham, or sodium methyldithiocarbamate.

These chemicals are available alone and in several products including: mixtures of methyl bromide and chloropicrin; 1,3-D and chloropicrin; 1,3-D and methyl isothiocyanate or MIC, the active breakdown product of metam; and a combination of 1,3-D, MIC, and chloropicrin. In addition, carbon disulfide and dazomet (tetrahydro-3,5-dimethyl-2H-1,3,5-thiodiazine-2-thione) are registered as fumigants but have fallen into disuse because of economic and/or toxicity problems at time of application.

Soil fumigants are the only pesticides that can provide, when used singly, broad-spectrum control of soilborne nematodes, disease organisms, weeds, and insects. Broad-spectrum but often less effective soil pest control may be achieved by the use of alternative nonfumigant compounds. These include the following three carbamates:

aldicarb: 2-methyl-2-(methylthio) propionaldehyde *O*-(methylcarbamoyl)= oxime;

carbofuran: 2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate;

oxamyl: methyl *N'*,*N'*-dimethyl-*N*-[(methylcarbamoyl)oxy]-1-thiooxamimidate;

and three organophosphates:

ethoprop: *O*-ethyl *S*,*S*-dipropyl phosphororodithioate;

fensulfothion: *O*,*O*-diethyl *O*-[*p*-(methylsulfinyl)phenyl]phosphorothioate;

fenamiphos: ethyl 4-(methylthio)-*m*-tolyl isopropylphosphoroamidate.

In addition to its nematicidal activity in the soil, oxamyl is a costly to apply, relatively inefficient systemic when applied to plant foliage.

The fumigants are general purpose compounds which control nematodes, soil fungi, soil insects, and weeds; however, activity can vary depending on the species involved. The general order of activity is chloropicrin approximately = methyl bromide > 1,3-D > metham. Weed seed are killed by methyl bromide and metham but not by chloropicrin or 1,3-D. The carbamates are active against nematodes and insects. The most active is aldicarb > carbofuran > oxamyl. One of the organophosphates, fenamiphos, is principally a nematicide, and fensulfothion and ethoprop are active against nematodes and insects. Fensulfothion's activity is > fenamiphos > ethoprop, but fenamiphos is most active against nematodes.

As noted above, the crops selected for this assessment are limited in number due to time and manpower constraints. They include citrus, cotton, potatoes, tobacco, tomatoes for fresh market, tomatoes for processing, and forest nurseries. Where possible, impacts of loss of soil fumigants for each crop have been identified for two regions, East and West, divided by the Mississippi River, except for forest nurseries data which are for Northern and Southern regions (See section on Forest Nurseries).

The crops and the states in the East and West regions are as follows:

Crop	States included in each region which contributed a significant share of the national 1982-1984 production
East	
Cotton	Ala., Ark., Fla., Ga., La., Miss., Mo., N.C., S.C., Tenn.
Potatoes	Ala., Conn., Del., Fla., N.C., Pa., R.I., Tenn., Vt., S.C., Va.
Tobacco	Conn., Fla., Ga., Ind., Ky., Md., Mass., Mo., N.C., Ohio., Pa., S.C. Tenn., W. Va., Va., Wis.
Oranges	Fla.
Grapefruit	Fla.
Lemons	—
Tomatoes	
Fresh	Ala., Ark., Fla., Ga., Ind., La., Md., Mass., N.J., N.Y., N.C., Ohio, Pa., S.C., Tenn., Va.
Processing	Del., Ind., Md., Mich., N.J., Ohio, Pa., Va.
West	
Cotton	Ariz., Ark., Calif., N. Mex., Okla., Tex.
Potatoes	Ariz., Calif., Colo., Idaho, Ill., Ind., Iowa, Mich., Minn., Mont., Neb., Nev., N. Mex., N. Dak., Ohio, Oreg., S. Dak., Okla., Tkex., Utah, Wash., Wyo.
Tobacco	—
Oranges	Ariz., Calif., Tex.
Grapefruit	Ariz., Calif., Tex.
Lemons	Ariz., Calif.
Tomatoes	
Fresh	Calif., Tex.
Processing	Calif., Colo., Tex.

Crop Acreages and Values

Average 1982-84 acreages and farm values for these crops (3) are:

Crop	Acreage (thousands)	Farm Value $ (millions)
Citrus	1,031	1,567
Cotton	10,067	3,298
Potatoes	1,304	1,845
Tobacco	847	3,048
Tomatoes (fresh and processing)	441	1,173 a/
Forest nurseries	6 b/	206

a/ $659 million fresh market; $514 million processing.

b/ Estimated by Assessment Panel.

Estimated Nematode Losses (In Yields)

Estimates of percentages of annual losses due to nematode damage for the six crops in this assessment, based on Special Publication No. 1, Society of Nematologists, 1971, (11) is as follows:

Crop	Estimated Percent Loss	Estimated 1983 $ Losses (Thousands)
Citrus	15	321,039
Cotton	5	130,818
Potatoes	10	207,772
Tobacco	5	141,912
Tomatoes, fresh	15	116,148
Tomatoes, processed	15	83,850
Forest nurseries	None available	

Estimated Soilborne Disease Losses - (In Yields) - (18)

The Plant Disease Subpanel estimated dollar losses for the six crops under study but did not assign percentage of loss figures.

Crop	Estimated 1983 $ Losses (Thousands)
Citrus	201,750
Cotton	323,570
Potatoes	458,310
Tobacco	159,950
Tomatoes (all)	221,210
Forest nurseries	NA

Estimated Losses Due to Weeds (In Yields) (6)

Crop	Estimated Percent Loss	Estimated 1975-1979 $ Losses (Thousands)
Citrus	5	61,683
Cotton	11	475,134
Potatoes	7	105,980
Tobacco	NA	---
Tomatoes (Fresh)	9	63,142
Tomatoes (Processed)	11	91,315
Forest Nurseries	NA	NA

Estimated Losses Due to Soil Insects (In Yields) (15)

Crop	Estimated Percent Loss	Estimated 1983 $ Losses (Thousands)
Citrus	No significant damage due to soil insects	
Cotton	No significant damage due to soil insects	
Potatoes	20	386,600
Tobacco	5	124,800
Tomatoes	No significant damage due to soil insects	

Methods for Estimating Impacts of Losses of Fumigants

A set of worksheets was designed to enable the preparation of a questionnaire that could elicit information needed to evaluate the biological effects and changes in control practices resulting from the loss of fumigants. These include effects on: soil pests, including plant-parasitic nematodes, plant diseases, weeds, and insects; production practices and costs; and crop yields and market values, as results of the use of alternative nonfumigant compounds. Data were also sought on possible needs for the use of nonchemical control means as additional alternatives.

Prior to its acceptance, the format of the questionnaire itself was evaluated and edited for its ability to generate pertinent information by the nematologists, plant pathologists, weed scientists, entomologists, and the agricultural economist on the Panel. The revised questionnaire was then used by the Panel members and by their individual contacts to develop the required biological data.

The pivotal aspects of the questionnaire consisted of requirements for data based on estimates for each crop, on acreages planted or in existence, acres treated, application methods and cost data, and projections for future control capabilities, limitations, and costs based on a set of seven scenarios or

interacting assumptions. These posit, in various combinations, the loss or availability of fumigants and their nonfumigant alternatives, with the understanding that various nonchemical control means may be used whenever they are practical. The resulting information makes it possible to estimate loss/benefit relations based on possible changes in crop yields and pest control costs that occur under each set of circumstances.

The seven scenarios are:

1. 1,3-D singly, and in mixtures, is lost. All other fumigants available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control.

2. Methyl bromide (MBr) singly, and in mixtures, is lost. All other fumigants plus alternatives available as in No. 1.

3. Chloropicrin singly, and in mixtures, is lost. All other fumigants plus alternatives available as in No. 1.

4. Metam is lost. All other fumigants plus alternatives available as in No. 1.

5. All fumigants are lost, but alternatives are available.

6. All fumigants and carbamates (aldicarb, carbofuran, and oxamyl) are lost for nematode control. Organophosphates (ethoprop, fensulfothion, and fenamiphos) are available.

7. Metam, chloropicrin, and organophosphates are available. All other fumigants and carbamates are lost for nematode control.

The information developed by the Panel represents an amalgam of estimates, interpretations of facts, and professional perspectives of the scientists on the Panel and the specialists they contacted. These data, which have undergone several critical reviews during which they were tested for reasonability and

practicality, form the basis of the biological part of this assessment of estimated potential impacts that cancellations of registrations of soil fumigants may have on the several crops in this study.

Problems in Soil Pest Control

If soil fumigants are lost by cancellations of registrations, growers will need to rely more heavily on alternative control strategies.

Cultural practices such as fallow, crop rotation, deep plowing, flooding, biological control, and the use of resistant crop varieties may, singly or in combination, be available to growers as means of reducing impacts of soil-dwelling pest damage on plants. However, none of them, with the possible exception of the use of resistant varieties, meets growers' needs as effectively as soil fumigants when it is practical to use them. Flooding is not practical in areas that have not been leveled as for irrigation, and fallowing and crop rotation frequently are not possible because of limitations on available land, or suitable marketing infrastructures for various crops. Biological control of pests is extremely difficult in the soil mass and practical methods are, almost without exception, not available.

Resistant varieties are available for very few crops, and frequently, those that have been available have been affected adversely by populations of pests described as being resistance-breaking biotypes. In addition, it takes relatively long periods of time to find resistance factors and then develop them into practical commercially-acceptable varieties. It is extremely difficult, costly, and time consuming, also, to build multiple resistance factors into new varieties in order to reduce unfavorable impacts that resistance-breaking pests can exert in the field. It is necessary, also, once genetic resistance is identified to make certain that the new varieties are horticulturally suitable and acceptable to processors and consumers. It appears that for the present and for the foreseeable future, commercial agriculture must continue to rely on chemical pesticides because they are the most practical and consistent means available for the control of crop-damaging pests.

Although more convenient to apply, nonvolatile or nonfumigant pesticides generally are not as acceptable to many growers as are soil fumigants. There are several reasons for this. With certain exceptions, nonfumigant compounds are less effective and less consistently efficacious than the soil fumigants in reducing or suppressing soil pest populations. Applications technology is not yet available to deliver them to target sites in the soil as efficiently as soil fumigants can be placed. Improvements in crop vigor, expressed as increases in yield and quality, are not as consistently high as can be expected following the use of soil fumigants.

Cost/benefit ratios are less defined for the nonvolatile pesticides than they are for the soil fumigants. Long-accepted management guidelines, which have been formalized in a 1968 study (13), require that the grower receive approximately the same three-to-five-fold increase for this pesticide expenditure, expressed as additional crop value, that is anticipated from outlays for fertilizers. These returns are realized more consistently from the use of soil fumigants. In addition, several of the nonvolatile pesticides that may be regarded as alternatives for the several soil fumigants are also potential candidates for cancellation because of their association with groundwater contamination. However, in the eventuality that one or more fumigants do become unavailable for use because of suspensions or cancellations, growers will have to adapt nonfumigant pesticides for use regardless of their relative drawbacks. This transition has already become evident. After the suspension of DBCP in 1977 and its later cancellation (9), alternatives were needed that could be used on established plants. Citrus growers have been using aldicarb as an alternative, and fenamiphos is being adapted for use in peach production.

There is a perception that additional soil fumigants may be lost and growers are reacting to this probability also. For example, the tomato transplant industry, which supplies seedlings for processing tomato production in the Northeast, Northern Ohio, Michigan, and Canada, used to depend on preplant soil fumigants. They now rely principally on ethoprop for the production of nematode-free plants that can move in interstate commerce and into export channels. Data are currently being gathered through the IR-4 Minor Use Pesticide Program to support the registration of fenamiphos for use in the production of tomato transplants.

Potential impacts of losses of soil fumigants will be most severe in nematode control followed by plant disease (i.e., soil fungus) control. Impacts will be less severe in weed and in insect control in the immediate future but problems may increase with time.

Why will impacts be most serious in nematode and fungus control? The answer may be related to the advanced state of control available for the management of the other pests. Large annual market volumes have resulted from the use of a multiplicity of insecticides and herbicides. Market size and its potential for profit have, in turn, resulted in an emphasis on increased research in these areas, that has resulted in larger numbers of new and more effective compounds. As a result, insect and weed control is at a comparatively more advanced level. If soil fumigation does become unavailable for control of these pests, there are other options available.

The stark differences in control capabilities help to underline the relatively primitive states of nematode control and soil disease control. There are approximately 175 active ingredients registered for use as insecticides and there are approximately the same number of herbicides. But there are only an approximate 50 registered fungicides and 20 registered nematicides. Of these, a number are registered for specific or narrow-spectrum applications only, and thus cannot be considered as being widely useful.

The small number of nematicides is especially critical. Only six are registered for use as soil fumigants: methyl bromide, 1,3-D, chloropicrin, metam, and two compounds that have fallen into disuse, carbon disulfide and dazomet. An additional six nonvolatile nematicides are registered for wide scale use: aldicarb, carbofuran, oxamyl, ethoprop, fensulfothion, and fenamiphos.

Why is the array of nematicides and fungicides so sparse? There are reasons other than the size of annual markets which are approximately $1.5+ billion each for herbicides and insecticides, and approximately $0.2 billion each for soil fungicides and nematicides. More is required of candidate compounds in these areas than is asked of potential insecticides and herbicides. Many target nematodes and fungi live deep in the soil mass, or within roots in

the soil. They are difficult to reach with pesticides because the soil mass itself is a formidable barrier. Many chemicals which may show activity in restricted laboratory _in vitro_ tests either cannot penetrate the soil masses containing the target pests in an efficient manner, or they are degraded or inactivated before they can reach sites of action in concentrations sufficient to be effective. For instance, chemicals that show dual insecticide-nematicide activity are usually active against nematodes only when used at dosages that range from two to five times, or more, than that of the insecticidal dosages. These differences in efficacy are so striking, and so indicative of increased registration risks, that industry programs often restrict their adaptive research with combination insecticide-nematicide compounds to evaluations against insects only. A classic illustration of safety-related considerations as they affect registration is phorate, an insecticide-nematicide with relatively high (EPA Category I) mammalian toxicity. It is in wide use at dosages of one pound active ingredient (a.i.) per acre for the control of the corn rootworm and the European corn borer, but its use as a nematicide has been severely restricted because of the dosage required for control. At the present time, the only registered use of phorate as a nematicide is at the rate of 16.0 pounds a.i. per acre applied to the soil for the production of commercially-grown Easterlily bulbs in the Pacific Northwest _only_.

Soil Fumigant Assessments by Crops

CITRUS

Background

Production of citrus and other perennials poses problems that the grower of annual crops does not need to consider. In the production of annuals, there is a respite every year; the grower has a preplant period during which he can use fumigants and/or other pesticides without regard to damage to established plants and then plant the annuals after an interval that allows for dissipation of the fumigant.

Citrus, obviously, does not provide this advantage. Thus, it is imperative that new planting areas for citrus, or other perennials, be as free of nematodes and diseases as practical field conditions permit, and that the new rootstocks intended for planting in the area be clean also. Heavy use of fumigants or the

use of sterile soil mixes (steam heat) helps to assure nematode- and disease-free root systems. Use of fumigants in the field, whether injected overall or applied deeply in designated tree sites, helps to ensure consistent reductions of pest populations to trace levels, or possibly, to numbers that are below detection levels. Reductions of nematodes and diseases in these circumstances may be as high as 95+ percent. Eradication, i.e, 100 percent kill, is not possible under field conditions.

The result is an optimum soil environment. The new trees attain vigorous growth rates, have only minimal problems with other soil organisms that may be associated with infections, and they yield well. The grower receives a proper return in crop value for the costs of preplant treatments. However, with time, unfavorable interactions occur between root systems that remain in place and residual surviving infections, or with secondary reinfections, that gradually increase from trace levels or below, toward economically significant higher numbers. The effects are unfavorable even after the trees have had the benefits of a good "head-start" but they are minimal compared with damage that can develop in trees growing in unfumigated soils. As these pests reproduce and cause increasingly heavy infections, rate of top growth is reduced, production is diminished, the effects of organisms that act as secondary invaders of roots become more evident, crop yields fall, and tree longevity is affected.

In production situations where soil fumigants are not or cannot be used to prepare the land for planting to perennials, the initial optimum soil environment does not exist. Without the optimum period of grace, trees start to show effects of damage due to root infections more rapidly.

When tree growth and production decline, whether early on, or relatively later after planting, the grower is faced with the need to reduce nematode and disease damage in and around the roots of established trees. Currently registered fumigants cannot be used because they are toxic to established plants. However, new formulations may improve efficacy and reduce phytotoxicity. This phytotoxicity limitation may be analogous to the loss of fumigants. The only nematicides and fungicides available are the nonvolatile compounds which can be tolerated by living roots. However, they must be applied

to the depths in the soil at which control is required. This is a problem in all but the light sandy soils.

In Florida, there is an indefinite degree of dependence on the use of aldicarb and fenamiphos in the soils around established trees. The use of aldicarb is associated with groundwater pollution. Research is attempting to adapt this compound for safe use.

In summation, the citrus industry requires the use of soil fumigants prior to planting to obtain optimum growth of trees. Nonfumigant alternative compounds, several of which have been associated with groundwater pollution, are not as efficient as the soil fumigants.

CITRUS - Pest Control

There are 668,000 acres in the East, which includes 72 percent of the national orange crop, 64 percent of the grapefruit, and all of the commercially-grown limes. In the West, 358,000 acres include oranges, grapefruit, and all of the commercially-grown lemons. The totals, in each region, include small plantings of minor citrus varieties.

Table 1 shows the degrees to which citrus production depends on soil fumigation to control soil-inhabiting plant-parasitic nematodes, diseases, weeds, and insects.

Citrus - Nematode Control

Nematodes

East - burrowing nematode (under quarantine), citrus nematode, ring nematodes, root-lesion nematodes, sting nematodes, and other ectoparasitic nematodes.

West - citrus nematode, ring nematodes, root-lesion nematodes, and ectoparasitic nematodes.

Citrus Seedbeds

There are approximately 1,100 acres in the East and 300 acres in the West that are treated for pest control each year (Table 1). Approximately 14 percent are treated to control nematodes, with methyl bromide or products containing methyl bromide (Table 2).

Data in Table 3 indicate that no impacts on seedbed yields or production costs are foreseen if 1,3-D, chloropicrin, or metam are lost singly (Scenarios 1, 3, 4). The loss of methyl bromide (Scenario 2) in the East would lead to the use of greenhouse-grown or container-grown stock, both of which would make use of sterile soil (steam heat) or soilless mixes. There would be an estimated one percent increase in seedbed yields due to the adoption of these growing methods, and costs per seedbed acre would increase $500 because of increased needs for watering and sheltering plants. There could also be indirect effects related to delays in adapting these growing methods to large volumes of seedlings required by the industry.

In the West, an alternative to methyl bromide use in seedbeds would be 1,3-D. This change would involve a reduction in control costs of $900 per acre but would also reduce seedling yields by 80 percent in the 280 seedbed acres involved.

The additional Scenarios would impose similarly large losses in seedbeds in the absence of all fumigants (Scenario 5), all fumigants and carbamates (Scenario 6), and the assumption that the only fumigants available would be metam and chloropicrin (Scenario 7). In each of these assumptions, the organophosphates would be available, and in the East, greenhouse and sterile-mix growing conditions would be available.

Losses under conditions of each of these last three Scenarios would cause control cost and yield reductions similar to those estimated for Scenario 2. With time, diminished nematode and disease control capabilities would become more severe in the seedbed industry and would be reflected in terms of reduced tree vigor as transplants from these seedbeds move into newly set-out groves, and reduced yields when trees reach bearing age.

Field Citrus

Almost all of the acreage in the East is in Florida, and the acreage in the West is found principally in California, Arizona, and Texas.

Available soil fumigants at concentrations used for pre-plant treatments are all toxic to living plant tissue.

In the East, an average of 1,335 acres, representing approximately 0.2 percent of the total, is in new or replanted acreage every year. Approximately 500 acres of this total are treated for nematode control every year, mostly with methyl bromide (Table 2). In the West, new and replanted acreage, comprises approximately seven percent per year of the total, or 25,000 acres. Of this, approximately 80 percent or 3,600 acres are treated, principally with 1,3-D.

In the East, little or no impact is anticipated as results of possible losses (Table 3) of 1,3-D, methyl bromide, chloropicrin, or metam (Scenarios 1, 2, 3, 4). The replacement for methyl bromide in Scenario 2, 1,3-D, would cause little or no negative impacts in yields and control costs, may be less convenient to apply, but would be as efficient a soil fumigant. In Scenarios 5, 6, and 7 (see footnotes in Table 3), the use of aldicarb and fenamiphos is not expected to be associated with changes in yield or treatment cost. Metam, which could be used under the conditions of Scenario 7, would not be the compound of choice for use in Florida citrus because of its inconsistency where irrigation capability is lacking.

In the West, no impacts are estimated under conditions in Scenarios 1, 2, 3, and 4. In Scenarios 5 and 6, there would be yield losses following the use of aldicarb or fenamiphos. The carbamates and the organophosphates are, in general, relatively inefficient in the West. At present, their levels of efficacy against nematode populations in western soils are not consistent. It is estimated that the sparseness of adaptive research and differences in soil types, moisture, pH, and climatic factors could, in the future, result in losses of up to 30 percent if these compounds were used in place of 1,3-D.

Such losses could be expected to increase as the cumulative results of diminishing nematode control capabilities, reduced tree vigor and longevity, and decreasing fruit yields become apparent. In addition, with time, reduced vigor of trees may become irreversible, and may lead to increased requirements for more frequent tree replacement. These estimated losses, due to the long-term effects postulated here, would eventually increase overall losses or, put another way, decrease overall yields, in citrus due to nematode damage, by approximately 50 percent.

Citrus - Disease Control

Diseases - root-rot, collar rot, bacterial canker.

Background

Satisfactory grove establishment requires the use of transplants to the field that are as free of disease as is practical. Transplants are produced either in seedbeds or in containers of sterilized soil or soilless mixtures. The latter practice is becoming dominant. Fifty percent of the transplants produced in Florida and Texas, and all produced in California and Arizona, are grown in soilless mixtures. Sterility of the planting medium for container-grown stock is assured by the use of steam heat when necessary.

The shift to soilless mixtures may be accelerated in Florida by the occurrence of bacterial canker. Soil fumigation in the seedbed, a practice of long standing, may now appear to be a temporary measure only, until a full changeover to soilless mixtures can be managed.

It is probable that this change will result in temporary loss of production capacity, until a necessary volume of container-grown stock can be established to meet the needs of growers. Stock grown in containers usually must be maintained under shelter because it requires more protection from temperature and moisture extremes than seedbed grown material.

In general, the use of soilless mixtures would increase costs of producing transplants by approximately 20 to 25 percent. This increase would result in a net increase of approximately one percent in the supply of transplants and a probable net increase in fruit production after they have been set out in tree sites.

During the transition period prior to full availability and use of soilless mixture production, metam probably would have to be used to treat a part of the field acreage. It would become obsolete when production volume becomes sufficient to meet growers' needs.

Seedbeds

Approximately 35 percent of the seedbed acreage in the East, i.e., Florida, and approximately 12 percent of acreage in the West, is treated to control diseases (Table 1). At the present time, the principal fungicidal treatment is methyl bromide in combination with chloropicrin (Table 4).

Losses of 1,3-D, and/or metam (Table 5, Scenarios 1, 4) are not expected to have impact, East or West. The loss of chloropicrin (Scenario 3) is not expected to have an impact either since methyl bromide is the major active ingredient in mixtures containing chloropicrin.

The loss of methyl bromide (Scenario 2), which can, if necessary, be used without the addition of chloropicrin as a warning agent, would cause yield reductions of approximately three percent in the East, due to the use of metam, a less effective alternative. These circumstances would speed the conversion to production in soilless mixtures in containers in Florida.

In the West, the loss of methyl bromide (Scenario 2) would expand the use of soilless mixtures as an alternative in the 300 acres of seedbeds. The costs of the alternative would increase the cost of production by $500; however, yields would increase by seven percent.

The loss of fumigants in Scenarios 5 and 6 and availability of organophosphates and cultural practices as alternatives would increase yields in the East by one percent. In the same Scenarios in the West, yields in seedbeds would increase by seven percent. This would increase production costs per acre but it is a temporary need, since the trend is toward production in soilless mixtures.

In Scenario 7, metam, chloropicrin and the organophosphates are available. The use of metam in the East would entail an estimated decrease of five percent in yield and a $200 per acre savings in control costs. In the West, the same decrease in yield is estimated, with no change in estimated control costs.

The use of soilless mixes would be more practical under the conditions of Scenario 7, with yield and control cost differences similar to those in Scenarios 5 and 6.

Field Citrus

In Florida, approximately four percent of the trees succumb to various causes each year. Approximately two percent of the replant sites are treated with methyl bromide. Fumigation is applied to tree sites, not overall. No field acreage in the West is treated in this manner.

It is not expected that possible unavailibility of 1,3-D, chloropicrin, or metam (Scenarios 1, 3, 4) would have impacts on field-grown citrus. The loss of methyl bromide (Scenario 2) in the East would stimulate attempts to use metam as an alternative for disease control. It would be less effective than methyl bromide; it would reduce yields by an estimated 25 percent, while reducing the costs of control by $400 per acre.

A similar loss of methyl bromide in the West would probably not produce similar impacts. There is, at present, a greater commitment in the West to the use of soilless mixtures for seedbed citrus. It could be expected that expansion of this effort would make a larger volume of clean rootstocks available that would minimize losses in the field because of their capacity to make vigorous and rapid growth.

Under conditions of Scenario 5, loss of all fumigants, Scenario 6, loss of all fumigants and carbamates, and Scenario 7, availability of metam and chloropicrin only, fenamiphos possibly could be substituted in the future. At the present time, however, there are insufficient research data for this chemical to warrant its routine use. Also, metam may not be practical for use because much of the irrigation capability in the East is not adaptable for its use. Field production in the East could decrease by an estimated 25 percent and these losses may become progressively greater in the future.

No impacts are expected to occur in the West because of their commitment to clean rootstocks produced without the use of pesticides.

Citrus - Weed Control

There is no significant use of soil fumigants for weed control in citrus.

Citrus - Insect Control

There is no significant use of soil fumigants for insect control in citrus.

COTTON - Pest Control

Over ten million acres of cotton are grown in the United States annually, 7,174,000 in the West and 2,893,000 in the East. In the East, 6,000 acres

are fumigated with 1,3-D and an additional 500 acres are fumigated with a product combining 1,3-D and chloropicrin. The fumigant choice in the West, 1,3-D, is used on 360,000 acres. Thus, fumigant usage, in percentages of acres planted, is 0.2 percent in the East and 5 percent in the West (Table 6).

Cotton - Nematode Control

Nematodes - root-knot nematodes, reniform nematodes, spiral nematodes, root-lesion nematodes, sting nematodes, and other ectoparasitic nematodes.

If 1,3-D is lost (Table 8, Scenario 1), there would be no adverse impact in the East because most of the dependent plantings, 6,500 acres, would be treated with aldicarb, assisted by the use of nematode-resistant varieties, crop rotation, and deep plowing, each of which can be expected to help reduce nematode populations or their effects.

In the West, the 36,000 acres that are usually treated with 1,3-D would be affected. The change would entail the use of aldicarb and crop rotation as alternatives. The change would be associated with an approximate reduction in yield of 3 percent, based on an average production of 546 pounds of cotton per acre, or the equivalent of 16.4 pounds per acre. Control costs would be reduced by $13 per acre. However, the efficacy of aldicarb is considered to be less than that of 1,3-D. The unavailability of the highly effective fumigant represents a danger of gradually increasing nematode problems over the long term.

No impacts are anticipated in the event of losses of methyl bromide, chloropicrin, or metam (Table 8, Scenarios 2, 3, 4).

If all fumigants are lost (Scenario 5), there would be no impact on cotton in the East because of the alternative use of aldicarb. In the West, the use of aldicarb and crop rotation as alternatives would be approximately the same as those estimated for the West in Scenario 1.

Estimated losses and/or increases in yields and treatment costs that may occur in Scenario 6, all fumigants and carbamates lost and organophosphates available, and in Scenario 7, only metam, chloropicrin, and organophosphates available, are the same, East and West, as those postulated in Scenario 1 for the West. The pesticide alternative in each of these scenarios would be phenamiphos.

Cotton varieties with nematode resistance play a major role in production and will help to minimize losses and related dislocations caused by the loss of 1,3-D, and the need to change over to aldicarb, fenamiphos, and various cultural practices. The varieties used exhibit resistance to one species of the root-knot nematode complex only, *Meloidogyne incognita*, which is widely distributed in cotton-growing areas and is considered to be a major pest. No resistance has been developed for ectoparasitic nematode pests. Rotation with resistant crops is perhaps the most practical alternative, but, unfortunately, there are only a few crops that can be rotated with cotton. These include sorghum, soybeans, and a number of vegetables, but generally, cotton acreage is considered to be insufficient to permit practical crop rotation. Table 8 indicates more or less generalized yield losses of 3 percent if soil fumigants are not available. These losses may escalate in the future as nematode populations slowly increase because of the lower efficacy of the nonvolatile or nonfumigant nematicides.

Disease Control - Cotton

There is no significant use of soil fumigants to control diseases of cotton.

Weed Control - Cotton

There is no significant use of soil fumigants to control weeds in cotton fields.

Insect Control - Cotton

There is no significant use of soil fumigants to control insect pests of cotton.

FOREST NURSERIES

Soil fumigation is not used on forest lands because this practice is not economically feasible. The following includes only information on forest tree nurseries that may employ soil fumigation for production of bare-root nursery stock. Certain producers of container-grown nursery stock may employ fumigation, but this practice is used on such a limited scale that it is not included.

The Forest Service has nine regions for the management of National Forests in the United States. However, for convenience of compiling this report and because of the similarity in growing conditions within the northern and southern states, these states were assigned to an arbitrary Northern Region and Southern Region. The Northern Region includes California, Connecticut, Idaho, Illinois, Indiana, Iowa, Maine, Maryland, Michigan, Minnesota, Nebraska, New Hampshire, New Jersey, New York, North Dakota, Ohio, Oregon, Pennsylvania, South Dakota, Utah, Vermont, Washington, West Virginia, and Wisconsin. The Southern Region includes Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, New Mexico, Oklahoma, South Carolina, Tennessee, Texas, and Virginia. The states of Arizona, Colorado, Kansas, Montana, Nevada, Wyoming, Hawaii, and Alaska were omitted because of the very small amount or the absence of bare-root nursery stock produced.

Data were obtained from 305 nurseries in the United States, including Federal, State, Soil Conservation Districts, private and Forest Industry nurseries. Most of it was compiled from 1981 reports and information. Many northern nurseries grow 2-year stock and a few grow 3-year stock; therefore, acreage of northern nurseries had to be estimated from existing reports for any given year. Data for southern nurseries are firm because most acres are planted to 750,000 seedlings every year to produce 1-year-old seedings for outplanting. In the Southern Region the value of 1-year-old pine seedlings ranges from $20 to $55 per 1,000 seedlings. In the Northern region the value of 2-year-old conifer seedlings ranges from $100 to $185 per 1,000 seedlings.

Planted Acreage and Seedling Production by Region

Region	Available for Production (acres)	Estimated Seedling Production (acres)	Seedlings Produced (X 1,000) (no.)
Northern	10,756	3,495	462,170
Southern	5,727	2,035	1,387,880

Production Practices

Currently, loblolly pine accounts for 60% of the bare-root seedlings produced in nurseries in the United States. Together, loblolly and slash pine outnumber, by more than 2 to 1, all other species combined. In total, southern pines account for nearly three-fourths of the reforestation in the United States. Over 90 percent of all seedlings produced in the United States are conifers. Therefore, only cultural practices for conifers are discussed in this report.

Most nurseries, particularly in the Southern Region, have either fine sand, sandy loam, or loamy sand soils. Some older nurseries have finer textured soils, but newer nurseries, established since 1960, have sandier soils that facilitate the use of mechanical lifters. Over 90 percent of the nurseries in the Southern Region and states on the Pacific coast that grow conifers use a broad spectrum soil fumigant before seeding the nursery beds. Fumigation provides excellent control for weeds, soilborne disease organisms, insects, and plant parasitic nematodes. Although indigenous ectomycorrhizal fungi are significantly reduced in fumigated soil, airborne basidiospores from these symbionts in nonfumigated soil surrounding the nursery rapidly recolonize the fumigated soil during the growing season following fumigation.

Most nurseries drill seed in rows in beds with commercial seeders. The desired density for southern pine seedlings ranges from 20 to 30 seedlings per square foot. After seeding, a mulch of pinestraw, sawdust, or bark is applied with a hydromulch.

Most nurseries use some system of rotation of conifer crops with cover crops. Approximately 40 to 50 percent of the nursery acreage in the Southern Region is grown in cover crops each year. Cover crops provide for organic matter maintenance, erosion protection, and soil stabilization, and improvement of the physical character of the soil. Nearly two-thirds of the southern nurseries use either 1:1 or 2:1 crop rotation (seedlings to cover crops). Sorghum-sudan (*Sorghum* spp.) or millet (*Panicum* sp.) are commonly used for summer cover crops and ryegrass (*Lolium* sp.) is the most popular winter cover crop.

The majority of the nurserymen apply an organic amendment to their soil. Sawdust is the common amendment, with bark or woodchips as alternatives, and amendments are usually applied every other year. Most nurseries currently employ irrigation during the growing season. Depending on location, frequency of rainfall and soil type, irrigation supplies from 0.5 to 5 inches of water per week.

Weeds cause problems accounting for varying degrees of conifer seedling mortality, and increase the cull rate. Even though preplant soil fumigation is generally used, weed seeds are introduced into seeded beds from areas adjacent to the seedlings or from the mulch. Consequently, even when soil fumigation is properly applied for weed control, postplant weed control is required. Most nurserymen depend largely on one or more chemicals for weed control following soil fumigation. Over 50 percent of the forest nurseries use mineral spirits to some extent. Other major chemicals used are oxyfluorfen, bifenox, napropamide, and prometryne.

Over 90 percent of the nurserymen apply commercial fertilizer to seedbeds prior to or at time of seeding and over 85 percent of them use additional fertilizer during the first growing season. Disease problems and fungicide use vary from region to region and nursery to nursery. Approximately 20 percent

of the forest nurseries report preemergence damping-off each year. Over 40 percent of the nurseries growing pines periodically encounter black root rot problems and those in the Southern Region occasionally have serious fusiform rust outbreaks. Captan and benomyl are commonly used for damping-off control. Bayleton and ferbam are used for fusiform rust control. Various foliar fungicides are used for occasional foliar blights. However, fumigation with methyl bromide is still the only effective means of controlling black root rot.

Increased use of genetically improved seed harvested from seed orchards is a noteworthy change in cultural practices in southern pine nurseries. However, there are no resistant varieties to avoid problems from pests.

Research needs indicated in both regions show that weeds and diseases are the two most critical problems. Problems from insects and nematodes are usually minor and only occasionally occur in some nurseries. However, if availability of general purpose soil fumigants is restricted for nursery use, it is expected that insects and nematodes will cause more severe and widespread problems in both regions.

Factors Affecting the Use of Fumigants

Soil moisture must be in the right range for effective fumigation with methyl bromide. In light sandy soils, the moisture should be slightly below field capacity; in heavy clay soils, it should be between 50 and 75 percent of field capacity. Soil temperature should be above 50°F at a 6-inch depth. Soil should be prepared in a fine, loose, friable condition to a minimum of 8 to 10 inches and be free of clods. There are only a few weeks in the spring and in the fall when these conditions can be met.

In the Southern Region, over 40 percent of the nurserymen fumigate before each seedling crop. Approximately 35 percent fumigate once for each two or three seedling crops; the remainder do not fumigate or fumigate only when serious problems arise. Spring fumigation is done to reduce the interval between fumigation and sowing, thus reducing the time for recontamination. The main reasons for fall fumigation are: 1) there is more time available for the

workers and 2) soil conditions are more favorable. In the Northern Region, many nurserymen employ fall fumigation. Also, in the North they fumigate, grow a 2-year crop, fallow for one year, then fumigate again.

Methyl bromide (MBr) is the broad spectrum fumigant generally used in forest nurseries for control of nematodes, weeds, and most soil-borne pathogenic fungi. Fumigant dosage rates vary between 250-600 pounds a.i. per acre; 350 pounds per acre is standard as a broad spectrum treatment. Another methyl bromide fumigant, MBr67 (67% methyl bromide and 33% chloropicrin), is often used to control pathogenic soil fungi having tough resistant spore stages (i.e., *Cylindrocladium* spp. and *Macrophomina phaseolina*). This formulation is not as effective for controlling weeds and grasses as MBr when used at the same rate. In the Northern Region nurseries, MBr67 applied at 400 pounds a.i. per acre is very effective for controlling weeds, damping-off pathogens, and plant parasitic nematodes.

The 1,3-D and metam fumigants have been used on a limited basis in several forest nurseries during the past several years, but their broad spectrum efficacy is less than that of methyl bromide fumigants. The cost of treatment is considerably less than methyl bromide fumigation and if spot treatment for nematodes or selected fungus pathogens is all that is required, then these materials are used as alternatives. Standard rates as recommended on the labels for these materials are followed.

Current Fumigant Use

Approximately 90 percent of all fumigation is done with methyl bromide fumigants in nurseries in both regions. Other fumigants used occasionally include 1,3-D, singly and in mixtures [Telone II (1,3-D)], Telone C17 (Telone 74% + chloropicrin 16.5%), Vorlex (1,3-D 40% + methyl isothiocyanate 20%), and metam (as Vapam®, Sodium N-methyldithiocarbamate dihydrate 32%). Since methyl bromide fumigants are most commonly used in both regions, estimates of acres treated each year were made only for these fumigants in this report.

Common Fumigants, Acres Treated and Average Rate in Each Region

Region	Fumigant	Estimated Acres Treated/Year	Average Rate (lb/A)	Cost ($)
Northern	MBr	150	350	950
	MBr67	670	400	950
Southern	MBr	1350	350	950
	MBr67	600	300	900

The cost of fumigation in forest nurseries varies depending on formulation, rate, and manner of application and region of the country. However, the average cost per acre for both regions, regardless of methyl bromide formulation, is $850 per acre if the nursery personnel do their own fumigation and $1,100 per acre if the fumigation is done by a contractor. In northern nurseries, the seedlings are grown for two or three years, depending on the tree crop. Each year, the acres fumigated are for planting a new two- or three-year crop. Calculation of the value of fumigation to this type of operation is quite different from that of southern nurseries where seedlings are grown for just one year.

Current Practices and Alternatives for Controlling Nursery Pests

In most nurseries in both Northern and Southern Regions, soil fumigants are so widely used that nematode and disease problems are rarely found. Consequently, alternative control practices are not employed by nursery operators. However, if fumigants were removed or restricted for use in forest nurseries, pest problems would become severe in a short time. Needed use of alternative fungicides, insecticides, and herbicides, additional tree seed, up to three times normal to offset losses, and additional acreage planted to compensate for losses caused by pests would cause esculated costs of production well beyond current costs.

In many nurseries in both Northern and Southern Regions, broad spectrum soil fumigants provide a good portion of the control for weeds, insects and diseases. However, since weeds remain a problem during the growing season following preplant fumigation, post plant applications of herbicides are used to markedly lower the amount of handweeding required to control this problem.

The most troublesome weeds in forest nurseries are crabgrass, nutsedge, bermudagrass, purslane, morningglory, sicklepod, goosegrass, carpetweed, fennel, clover, barnyardgrass, pusley, broomsedge, cocklebur, crowfootgrass, flathead sedge, and spurge.

Herbicides Commonly Used in Forest Nurseries

Herbicide	Applications and Rates	Estimated Acres Treated	
		Southern Region	Northern Region
oxyflurofen	1-2 appl./yr;	300	100
bifenox	2-3 appl./yr; 2 lbs/A	320	125
napropamide	1-2 appl./yr; 2-8 lbs/A	200	185
prometryne	1-2 appl./yr; 2-3 lbs/A	150	100
diphenamid	1 appl./yr; 4-8 lbs/A	170	100
nitrofen	2-5 appl./yr; 2-6 lbs/A	210	75
glyphosate	1 appl./yr; 0.5 lb/A	50	N/A
Mineral spirits	1-10 appl./yr; 20-30 gal/A (Average 130 gal/A/yr)	600	200

If soil fumigants become restricted or lost for use in forest nurseries, none of the above would provide the same control currently obtained with soil fumigation. Handweeding efforts would have to be increased three times the current levels, particularly in nurseries in which perennial weeds are a problem (i.e., nutsedge and/or bermudagrass).

Before widespread use of soil fumigants, handweeding costs ranged from 20 to 40 percent of total production costs. Today, with general use of soil fumigants and postplant herbicides, handweeding costs only 2 to 4 percent of the production costs. The median values of handweeding during the growing season, depending on areas of the country, range from $155 to $490 per acre.

The common soilborne diseases in forest nurseries are damping-off, fusarium root disease, charcoal root rot, black root rot of pine, Phytophthora root rot, and Cylindrocladium root rot. Soil fumigation with methyl bromide fumigants provide excellent control of these diseases. Root rots caused by *Macrophomina* or *Cylindrocladium* have resistant resting spores (sclerotia) that survive for years in the soil. Soil fumigation with MBr67 is currently the only satisfactory way to control diseases caused by these fungi. Generally, cultural methods on the whole have not been effective in controlling most of the soilborne diseases in nurseries which do not employ soil fumigation. Chlorothalonil, metalaxyl, and benomyl have been effective in controlling certain diseases when used as drenches following soil fumigation.

Estimated Impact of Losing Fumigants

Scenario 1. Only 1,3-D lost.

This loss would have little impact on forest nurseries. The few nurseries that use 1,3-D fumigants could convert to MBr or metam fumigants and maintain excellent pest control at very little or no increase in cost.

Scenario 2. MBr lost, all others available.

Use of 1,3-D and metam fumigants would increase markedly. 1,3-D mixtures and metam would be employed and would provide some degree of control of weeds, nematodes, diseases and insects. Based on previous research and experience, none is as consistently effective as MBr fumigants. All three are significantly less effective in controlling weeds and diseases, particularly those caused by Cylindrocladium and Macrophomina, than MBr fumigants. Therefore, it is estimated that losses in both the Northern and Southern Regions would approach 25 percent in three years. This seedling loss would account for a 15 to 20 percent decrease in acres planted.

The Southern Forest Resources Analysis Committee Report (USDA Forest Service 1969) called for 60 million acres to be forested by the year 2000. Regeneration rates in the South in 1985 were barely achieving half the goals set by the report. A major bottleneck to achieving these goals is inadequate nursery capacity. If MBr is lost, nursery capacity will be further diminished, resulting in a greater shortfall in achieving regeneration goals. The 1985 Farm Bill and Conservation Resource Program (CRP) will further increase tree planting trends. The CRP goal is to plant five million acres of highly erodable farm lands during the 5-year probram.

Scenario 3. Only chloropicrin lost.

The use of chloropicrin in combination with methyl bromide, in the form of MC-33, is important in northern production areas. Production of suitable transplants in northern locations would be severely restricted if chloropicrin is not available for use.

Scenario 4. Only metam lost.

There would be virtually no impact on forest nurseries because so little of this fumigant is currently used.

Scenario 5. All fumigants lost.

Weed control would be strongly impacted. Soilborne diseases would become very severe in 3 years after fumigants are lost. Certain nurseries in both Regions would close or stop producing seedlings of most forest tree species with the increase in disease problems. Other nurseries would increase seedling production by planting more acres to compensate for seedlings lost to weed competition and increased diseases. Seedling quality would also be lowered, resulting in poorer field performance.

Losses in nurseries in both Northern and Southern Regions would approach 50 percent in 2 to 3 years. Seedling losses would account for at least a 40-percent decrease in acres planted annually. Handweeding costs in nurseries would approach 30 percent of total production costs.

Scenario 6. All fumigants and aldicarb, carbofuran, and oxamyl lost.

The impact would be virtually the same as for Scenario 5.

Scenario 7. All lost except metam and chloropicrin.

It is estimated that this would be the same as for Scenario 2.

POTATOES - Pest Control

The total acreage planted to potatoes each year is approximately 1,304,000, of which 273,000 are in the East, and 1,031,000 are in the West (Table 14). Approximately 13,348 acres, or 5 percent of acres in the East, and 238,000 acres, 23 percent of the total in the West, are treated with fumigants for pest control. 1,3-D is used on approximately 63 percent of this acreage; 10,600 acres in the East and 145,800 acres in the West (Table 15). In addition, metam is used on approximately 92,000 acres or 37 percent of the treated potato acreage in the West.

Potatoes - Nematode Control

Nematodes - root-knot nematodes, Golden nematode (or potato cyst nematode), root-lesion nematodes, and several species of ectoparasitic nematodes.

1,3-D is heavily relied on for control of nematodes in potatoes. If 1,3-D does become unavailable (Table 16, Scenario 1), approximately 20 percent of the acreage formerly treated with it would be treated with metam. This change would occur mostly in the West, and would entail losses of approximately 15 percent in yields and increased costs of $50 per acre in the equivalent of over 25,000 acres.

The loss of metam (Scenario 4) would have no effect in the East where it is not used on potato acreage. In the West, the use of 1,3-D or an alternative would be on acreage best suited for metam because of pivot irrigation and other irrigation capabilities. Yields would increase 15 percent and costs per acre for control would decrease by $50 in affected fields.

If all fumigants were lost (Scenario 5), growers would use aldicarb, carbofuran, or ethoprop in their stead in the majority of the treated acreage. Annual estimated yield losses, East and West, would be 15 percent and costs of control would increase by $50 per acre. The yield losses sustained with the onset of Scenario 5 conditions would increase with time. Less efficient nematicides, such as the available nonvolatile compounds, would allow nematode populations to build up. As this occurs, yield reductions would become more severe, possibly increasing to 30 percent or more.

Impacts in Scenario 6, all fumigants and carbamates lost, are expected to be similar to those reported for Scenario 5. Ethoprop would be used, East and West, and would be associated with 15 percent reductions in yields and increased control costs of $50 per acre.

In Scenario 7, metam, chloropicrin, and organophosphates available, all other fumigants and carbamates lost, metam and ethoprop would be used as alternatives to 1,3-D, with approximately the same 15 percent yield losses and increase in control costs of $50 per acre.

No impacts are anticipated due to losses of methyl bromide (Scenario 2) or chloropicrin (scenario 3).

In most potato acreage, 1,3-D is the nematicide of choice when nematode infections must be controlled. Growers and custom applicators are familiar with the parameters of physical factors such as soil moisture, soil temperature, and soil types that govern its most efficient use, and its use is associated with reduced nematode infections and increased potato yields.

Alternatives such as metam require irrigation capabilities that may be lacking in certain areas. Under these circumstances, metam is usually difficult to apply and inconsistent in efficacy. Other alternatives, such as aldicarb, carbofuran, or ethoprop cannot penetrate the soil mass as efficiently as soil fumigants.

A probable result of the unavailability of 1,3-D, coupled with a lack of efficacious alternatives, could be a sharp reduction or elimination of potato production, and/or sharp income losses, in certain areas now devoted to potato production.

The Golden nematode, a serious parasite of potatoes, occurs in several areas in New York, and is under a Federal-state quarantine. The New York SAES has developed potato varieties resistant to this nematode.

Potatoes - Disease Control

Diseases - Verticillium wilt

Soil fumigation for disease control is used on approximately 5 percent or 13,300 acres in the East, and 6 percent or 58,720 acres in the West (Table 14). Fumigants are applied principally for the control of Verticillium wilt, the so-called Early Dying Complex. The success of control practices for this purpose suggests the great dependence the industry places on disease and nematode control.

The principal fumigant is metam which is most efficient when it is applied in irrigation lines such as chemigation systems (Table 19). A lesser acreage is treated with 1,3-D.

In Scenarios 1, 2, 3, losses of 1,3-D, methyl bromide, or chloropicrin (Table 20), no impacts are anticipated in the East. If 1,3-D/MIC were lost in the West (Scenario 1), metam use would cause no changes in yield and control costs would decrease by $425 per acre. If metam becomes unavailable (Scenario 4), the use of a 1,3-D-mixture would cause no changes in yields but would increase costs of treatment by $425 per acre. The loss of all fumigants (Scenario 5), and all fumigants and the carbamates (Scenario 6) would leave growers with no alternatives, resulting in yield losses of approximately 25 percent, East and West, and decreases in treatment costs of $263 per acre in the East and $456 in the West. Metam would be available for use as an alternative in Scenario 7. No impacts would occur in the East, and there would be a decrease in treatment costs of $425 per acre in the West on acreage treated with 1,3-D/MIC.

Varieties resistant to Verticillium wilt could be substituted for susceptible varieties. This is, however, not an alternative because market demands dictate that certain acreages of various varieties be planted. The use patterns for the resistant varieties presently being grown practically dictate the number of acres of resistant varieties that can be planted.

If resistant varieties with the desirable characteristics of the susceptible varieties could be developed and introduced, there would, of course, be no need for soil fumigation. However, ongoing research efforts have failed to resolve the problem. Disease control will, then, be dependent on soil fumigation for the foreseeable future.

The loss of all soil fumigants would increase the incidence of disease and lead to acreage yield decreases of 100 cwt per acre.

Potatoes - Weed Control

Metam is applied by irrigation in some areas of the northwest (Table 17). This represents the only use of fumigants for weed control in potato fields. Disease and/or nematode control is the primary objective of metam usage, but some fields obtain a degree of weed control.

A standard herbicide program in addition to metam is necessary since complete weed control is not obtained with metam alone. The loss of metam (Table 18, Scenarios 4, 5, 6) would save growers its cost of $250 an acre and would result in an average 2-percent loss in yields because of reduced weed control. Therefore, the use of metam for weed control only is not economical for potato production given the availability of more suitable herbicides. Scenarios 1, 2, 3, and 7 would not be applicable.

Potatoes - Insect Control

There is no significant use of soil fumigants to control insect pests of potatoes.

TOBACCO - Pest Control

All commercially-grown tobacco is produced in the East (Table 21). Seedbed acreage is 14,000, all of which is completely dependent on fumigant treatments to control nematodes, diseases, and weeds. Total field acreage is 833,000. Of this, 50 percent is treated for nematode control, and 7 percent of the acreage is treated for the control of diseases.

Tobacco - Nematode Control

Nematodes - root-knot nematodes, root-lesion nematodes.

Seedbed Tobacco

Nematode control in tobacco seedbeds is heavily dependent on methyl bromide, used singly and in mixtures with chloropicrin. Only 13 percent of the acreage is treated with a 1,3-D/MIC mixture, or with metam (Table 22).

If 1,3-D becomes unavailable (Table 23, Scenario 1), methyl bromide could be used. Seedbed yields would increase by 40 percent and costs per acre for treatment would increase by $175.

The loss of methyl bromide (Scenario 2) could be managed by the use of 1,3-D plus MIC or metam. Yields would decrease by approximately 40 percent and the cost of nematode control would decrease by $175 per acre.

Under conditions of Scenario 5, all fumigants lost, and carbamates and organophosphates available, and Scenario 6, all fumigants and carbamates lost and organophosphates available, impacts would be identical. The use of alternatives such as ethoprop or fenamiphos, coupled with planting of resistant varieties and the use of cultural practices such as crop rotation, and/or deep plowing, would reduce yields by 40 percent, and decrease the costs of control by $800 per acre.

In Scenario 7, in which metam, chloropicrin, and the organophosphates are the only nematicides available, the use of metam would incur the same impacts as those predicted for Scenario 2; yields would decrease by 40 percent and the costs of control would fall by $175 per acre.

In time, yield losses would escalate above those indicated in all the scenarios and the use of sterile mixes would be adopted for seedling production.

Scenarios 3 and 4, which suppose the loss of chloropicrin and metam, respectively, would have no impact.

Methyl bromide, applied for nematode control purposes in the seedbed, also controls diseases, weeds, and insects.

Field Tobacco

Approximately 50 percent of tobacco fields, or 416,000 acres, are fumigated for nematode control purposes. Approximately 79 percent of this acreage is treated with 1,3-D (Tables 21, 22).

If 1,3-D is not available (Table 23, Scenario 1), alternative nonvolatile chemicals used would be ethoprop or fenamiphos, and possibly one or more of several nonchemical means would also be used. These would include planting of resistant varieties, crop rotation, fallow, and deep plowing. Tobacco yields would decrease by approximately 4 percent, and the costs of nematode control would increase by approximately $110 per acre.

Changes in yields and control costs would be identical under conditions predicated in Scenario 5, all fumigants lost but carbamates and organophosphates available; Scenario 6, all fumigants and carbamates lost but organophosphates available; and, Scenario 7, only metam, chloropicrin, and the organophosphates available. Several chemical and nonchemical alternatives such as ethoprop, fenamiphos, resistant varieties, crop rotation, and deep plowing would be used. The decreases in yield of approximately 4 percent and increases of $110 per acre in control costs would be similar to those estimated in Scenario 1.

Losses of methyl bromide, chloropicrin, or metam (Scenario 2, 3, 4) would not have impacts on tobacco production or treatment costs.

Research has developed resistance to a root-knot nematode, _Meloidogyne incognita_, a widely-distributed species, in several tobacco varieties. They are satisfactory varieties but the present perception of the extent of their usefulness emphasizes the extremely difficult and time-costly problems that exist in this research.

Since the introduction of the first variety, NC95, four races of _M. incognita_ have been identified, and it is now understood that NC95 is resistant to races 1 and 3 only. In addition to its susceptibility to races 2 and 4, NC95 and other varieties are also susceptible to three other widely-distributed species of the root-knot nematode, _M. arenaria_, _M. javanica_, and _M. hapla_.

Tobacco - Disease Control

Diseases - Bacterial wilt, Black shank, root rots.

Soil fumigants are used for disease control in 100 percent of tobacco seedbeds and in seven percent of tobacco field acreage (Table 21). These figures indicate a successful reliance on the capability of disease- and nematode-free transplants to make vigorous growth after they are transferred into the field.

Seedbeds

The losses of several or all of the soil fumigants (1,3-D in Table 27, Scenario 1; methyl bromide in Scenario 2; all fumigants in Scenario 5; all fumigants and carbamates in Scenario 6; and, in Scenario 7, the availability of metam, chloropicrin, and the nonvolatile organophosphates) would encourage the use of either soilless mixtures or steam-sterilized soil as planting media. Producers would rely on container-grown transplants for disease control. These practices would increase yields by 10 to 15 percent and increase costs by the equivalent of $200 per acre using the Speedling® system.

The lossses of chloropicrin or metam (Scenario 3, and 4, Table 27) would have no impact.

Field Production of Tobacco

Diseases and weed control in tobacco fields is, frequently, a bonus resulting from soil fumigation for nematode control (Tables 21, 22). The principal fumigant for this purpose is 1,3-D, used singly or in mixtures.

The most commonly used fungicide for the control of Black Shank, a relatively wide-spread disease of tobacco, is metalaxyl (N-(2,b-dimethylphenyl)-N(methoxyacetyl)-alanine methyl ester, or Ridomil®. Metalaxyl would serve as an alternative in place of 1,3-D under several Scenarios in Table 27: loss of 1,3-D (Scenario 1); loss of all fumigants (Scenario 5); loss of all fumigants and carbamates (Scenario 6); and loss of all fumigants except metam and chloropicrin (Scenario 7).

In each of these assumptions, metalaxyl, applied at the rate of one to two quarts per acre would not affect yields and would reduce treatment costs by $180 per acre. The results, however, would not be as broad-spectrum in effect as would fumigation with 1,3-D. 1,3-D controls fungi, weeds, and insects, when used at nematicidal concentrations. Metalaxyl is a fungicide only.

The losses of methyl bromide, chloropicrin, and metam (Scenarios 2, 3, 4) would have no effects on disease control programs in tobacco.

Tobacco - Weed Control

Fumigation is necessary for weed control in 100 percent of the approximately 14,000 acres of tobacco seedbeds that are in production each year. Control is primarily by means of methyl bromide fumigation (Table 24). Herbicides and occasional handweeding are used also.

If methyl bromide is lost (Table 25, Scenario 2), metam or a 1,3-D/MIC mixture, plus increased handweeding, would maintain production at present levels, assuming weeds were the only pest problem encountered. The loss of all

fumigants (Scenario 5), or loss of all fumigants and carbamates (Scenario 6) would necessitate the use of extensive handweeding. There would be no reductions in yields but control costs would increase drastically if handweeding were employed. In Scenario 7, which assumes the availability of metam, chloropicrin, and organophosphates only, the use of metam and handweeding would maintain yields at present levels.

The losses of 1,3-D, chloropicrin, and metam (Scenarios 1, 3, 4) would have no impacts.

In general, with loss of fumigants, the use of available alternative fumigants and handweeding would maintain tobacco seedbed production at current levels if weeds were the only pest problems encountered. However, because of the impracticality of the extensive handweeding required, a shift into sterile mixes may be indicated.

Soil fumigants are not used to control weeds in tobacco fields.

Tobaccco - Insect Control

There is no significant use of soil fumigants to control insect pests of tobacco.

TOMATOES - Pest Control

There are approximately 440,000 acres in tomato production: 6,500 acres of seedbeds, 127,000+ acres grown for the fresh market (Table 28), and 307,000 acres produced for the processing industry (Table 35).

All of the seedbeds are in the East. Tomatoes for the fresh market are grown on 94,000 acres in the East, and 33,800 in the West (Table 28). Tomatoes grown for processing total 59,000 acres in the East and 248,000 in the West (Tables 35).

TOMATOES - Pest Control

In the East, fumigation treatments for nematode and disease control in seedbeds are 46 and 39 percent, respectively, and are 61 and 63 percent, respectively, in field acreage. Weed control by fumigation is zero in seedbeds and 58 percent in fields in the East.

In the West, seedbeds are not part of the production schedule because they are not economical. Fumigation treatments for the control of nematodes and disease are applied in eight and nine percent of field acreage, respectively. Fumigants are not used for weed control in the West.

Tomato transplants are shipped in interstate commerce, principally to the Northeastern states, Northern Ohio, and Michigan, and they are shipped to Canada also. They are essential adjuncts to the well-being and productivity of the tomato crop grown in these areas for processing and for the fresh market. The relatively short growing season in these northerly locations allows for maximum practical field production only if transplants are available to, in effect, extend the season.

In order to be shipped interstate and to Canada, transplants must meet the regulations of various state quarantines and those of the United States Department of Agriculture's Animal and Plant Health Inspection Servicce (APHIS). They must be free of nematodes, usually root-knot nematode infections, and diseases in order to be shipped.

Tomatoes - Nematode Control

Nematodes - root-knot nematodes, root-lesion nematodes, and ectoparasitic nematodes.

Tomato transplants for the north are grown on approximately 3,000 acres of seedbeds in Georgia. To a certain extent, this part of the industry is outside the purview of this report on the assessment of soil fumigant usage, but it does represent an interesting and, possibly, prophetic sidelight.

These growers have been able to adapt and use a nonvolatile, nematicide, i.e., a nonfumigant, in their production system to meet quarantine demands. Nematodes are controlled in approximately 90+ percent of the seedbed acreage by the use of ethoprop, one of the available organophosphates. It is applied prior to seeding in a 10-percent granular formulation at a rate of 8 pounds active ingredient per acre, and it is incorporated in the soil. Costs, including the chemical and application total approximately $100 per acre. The remainder of the acreage is fumigated, before planting, with 1,3-D injected at the rate of 15 gallons per acre at a cost of $150 per acre. It is possible that the use of ethoprop and fenamiphos in seedbeds will increase with time, since they are considered to be acceptable from the point of view of environmental safety.

Other Seedbeds

In the East, approximately 2,600 acres are fumigated with a 1,3-D-containing mixture (Table 29). If 1,3-D is lost (Table 30, Scenario 1), methyl bromide would be used in its place, producing a 10-percent increase in yield but increasing costs by $300 per acre.

In the absence of methyl bromide (Scenario 2), a 1,3-D-containing mixture could be used to treat approximately 400 acres. Seedbed yields would be reduced by 20 percent and costs of treatment would be $300 less per acre. If all fumigants were lost (Scenario 5), or all fumigants and carbamates were lost (Scenario 6), ethoprop, the nonfumigant nematicide used to produce nematode-free tomato transplants for interstate shipment and export, could be used. However, growers would need some time to fit ethoprop into their production practices. Under each protocol, yields would decrease by an estimated 20 percent and treatment costs per acre would decrease by $400. In Scenario 7, metam, which would be the only available fumigant, would reduce yields by 20 percent and reduce control costs by $400 per acre.

No impacts are foreseen if chloropicrin (Scenario 3) or metam (Scenario 4) are lost.

In the West, it is estimated that cancellations of soil fumigants would have no impacts on tomato transplant production. The use of soilless mixes or sterile soil (steam heat) would avoid the issue of soil fumigant availability.

It is probable that the entire tomato transplant industry that supplies seedlings for fresh market field production could, if need be, move to the use of sterile soil or soilless mixes. However, the flexibility that exists in field production could be lost if growers were forced to change from established production practices to more costly alternatives such as soilless or sterile mixes.

Fresh Market Tomatoes - Field Production

The bulk of fresh market tomato production is dependent on primary prevention of pest damage. Seedlings are grown in fumigated soil, and field soils which receive the seedlings are fumigated also. There is heavy reliance on methyl bromide for this purpose in the East and on 1,3-D in the West.

If 1,3-D is lost (Table 30, Scenario 1), methyl bromide would be the alternative in the East to the extent to which it can be used economically. It would increase yields 20 percent and increase costs by $150 per acre. In the West, if oxamyl were to be used in place of 1,3-D, it would be associated with yield reductions of 20 percent at no increase in treatment costs per acre.

The loss of methyl bromide (Scenario 2) would encourage the use of a 1,3-D-containing mixture in the East, reducing yields 20 percent and reducing treatment costs by $150 per acre. In the West, 1,3-D, used in place of methyl bromide, would reduce yields 30 percent and lower treatment costs by $750 per acre.

In Scenarios 5 and 6, all fumigants lost, and, all fumigants and carbamates lost, respectively, there would be no suitable options available. In the East, 60 percent yield reductions would occur, and costs would be reduced by $500 per acre. In the West, cultural practices such as deep plowing and rotation would result in yield reductions of 20 percent, and costs of treatment per acre lowered by $275.

Metam and chloropicrin would be the only soil fumigants available in Scenario 7. Metam used in the East would cause reductions in yields and treatment costs per acre of 20 percent and $50, respectively. In the West, chloropicrin use would cause no changes in yields or in treatment costs.

It is probable that the loss of fumigants would cause sharp reductions in the acreage currently devoted to fresh market tomato production, and the possible loss of a large part of the industry to other countries. The use of organophosphates and/or carbamates may not present practical alternatives in certain areas because of inconsistent nematicidal efficacy when applied under currently registered use patterns and label restrictions.

Processing Tomatoes - Field Production

Nematicides are not usually used in the East in the production of tomatoes for the processing industry (Table 35). Small profit margins make them impractical. Primary reliance is on nematode-free transplants.

In the West, 1,3-D is used to fumigate approximately 33 percent of the 248,000 acres. There is no significant dependence on any other nematicide. If 1,3-D is lost (Table 37, Scenario 1) there would be no practical alternative, and yields and costs per acre would decrease by 10 percent and $100, respectively. Similar losses are anticipated under conditions of Scenario 5, all fumigants lost, Scenario 6, all fumigants and carbamates lost, and Scenario 7, metam and chloropicrin only fumigants available.

Losses of methyl bromide (Scenario 2), chloropicrin (Scenario 3) or metam (Scenario 4) would have no impact.

Tomatoes - Disease Control

Diseases - Southern blight, Bacterial wilt, Bacterial spot, Bacterial speck, Brown root rot, Verticillium wilt, Fusarium wilt, damping-off complex.

Transplants and Fresh Market Production

Soil fumigation for disease control is practical for transplant and field production as a management tool applied to intensive growing systems. Intensively-managed farm operations would suffer if certain soil fumigants were lost.

Fresh market tomatoes may be produced extensively or intensively. Extensive practices include the usual ground preparation, planting seeds or transplants, and applying the usual cultural practices for growing, harvesting, and marketing.

Intensive practices include all of the foregoing, and one or more of the following: soil fumigation, use of plastic strip ground covers, installation of drip irrigation systems, and various staking and tie practices. Production costs can range from $1,200 to $6,000 per acre, depending upon practices used.

Many northern tomato growers depend upon transplants from the South. Such transplants may be grown in fumigated soil "in the ground," or they may be produced in soilless mixes or in steam-sterilized soil in containers sheltered in various structures. The use of soil fumigants can, thus, be avoided, but this practice would increase unit costs of the transplants by approximately 50 percent, from approximately 3.5 - 4.0 cents to approximatly 6.0 cents.

No economically feasible alternative to fumigation is conveniently available for field production. The alternatives may be increases in intensive cultivation and rotation.

In the East, methyl bromide, singly or in mixtures with chloropicrin, is the principal fumigant used for control of diseases in fresh market field production (Table 33), and 1,3-D-containing mixtures are used primarily in transplant production.

If methyl bromide is lost (Table 34, Scenario 2) or if metam and chloropicrin are the only fumigants available (Scenario 7), metam could be used for transplant production, with a 15-percent reduction in yields and $250 per acre decreases in control costs. If all soil fumigants are lost (Scenario 5), or all fumigants and carbamates are lost (Scenario 6), there would be no alternative available. Losses would be 30 percent in yields of transplants, and control costs per acre would decrease $650. Scenarios 1, 3, and 4, losses of 1,3-D, chloropicrin, or metam would have no impacts in the seedbed.

In field production in the East, metam as an alternative to the loss of methyl bromide (Table 34, Scenario 2), or under circumstances in which only metam is available (Scenario 7), losses in yields would be 7 percent and reductions in control costs would be $50 per acre. A methyl bromide mixture used if metam is lost (Scenario 4) would increase yields seven percent and increase control costs by $100 per acre. In Scenario 5, all fumigants lost, and Scenario 6, all fumigants and carbamates lost, there would be no alternatives available. Yields would drop by 14 percent and costs by $300 per acre. Conditions predicated in Scenarios 1 and 3 would have no impact.

In the West, no fumigants are used in seedbeds. The bulk of field-grown tomatoes is direct seeded in the field.

Field production in the West depends on metam, and, to a lesser extent, on a methyl bromide mixture for protection against diseases. Metam would be used in place of methyl bromide (Table 34, Scenario 2) with a loss of 6 percent in yields and a reduction of $600 per acre in control costs. The loss of metam (Scenario 4) would produce the reverse, an increase of 6 percent in yields and an increase of $600 per acre in costs of control. In Scenario 7, in which only metam is available, impacts would be the same as those estimated in Scenario 2. Losses of all fumigants (Scenario 5), and of all fumigants and carbamates (Scenario 6) would reduce yields 10 percent and lower treatment costs per acre by $500. Scenarios 1 and 3, losses of 1,3-D or chloropicrin would have no impacts.

Where soil fumigation is used for disease control, yield increases of as much as 2,500 lbs. per acre have been reported.

Processing Tomato Production

As noted previously, the processing tomato industry relies on transplants produced in Georgia. In the East, processing tomato acreage is not fumigated (Table 35). One-third of the acreage in the West is treated with 1,3-D (Tables 35, 36) primarily for nematode control.

In the East, none of the Scenarios (Table 37) would have impact directly on disease control, but the processing industry, itself, would be devastated if transplant shortages occurred. Attempts to compensate by use of direct seeding methods would not be practical. The growing season in the Northeast and in Canada is too short to support direct seeding in the field.

Tomatoes - Weed Control

Transplants and Fresh Market Production

Fumigants are used for fresh market tomato production in the Southeastern United States, with 100 percent usage in Florida. Fumigant is applied under plastic mulch which remains in place within the crop row during production. Methyl bromide is the primary active ingredient used (Table 31) to control weeds. Weeds can grow through the hole made in the mulch for planting the crop, and sedges can grow through the plastic itself. Herbicides, and, in certain cases, cultivation, can be used to control weeds in bare soil areas between rows of plastic mulch.

Losses of methyl bromide, of all fumigants, of all fumigants and carbamates (Table 32, Scenarios 2, 5, 6) and availability of metam only (Scenario 7) would require the use of an alternative herbicide, napropamide, and handweeding within the crop row. The lower cost of the herbicide would offset the increased costs of handweeding, and there would be no impacts in yields or in control costs per acre. The plastic mulch provides weed suppression so that handweeding could be restricted to weeds that escaped exposure to the herbicide and grew through holes in the mulch made for the crop plants.

Scenarios 1, 3, and 4, losses of 1,3-D, chloropicrin, and metam, respectively, would have no impacts.

The use of fumigation cannot be justified for weed control alone if handweeding labor is available. However, increased handweeding may not be a reasonable alternative in this country at this time. Lower labor costs in the Caribbean area could result in attracting a significant part of the fresh market tomato industry away from the continental United States if fumigants were lost.

Processing Tomatoes

Historically, no fumigants have been used for weed control in the production of processing tomatoes. At present, there are no herbicides that control nightshade adequately, making handweeding a requirement. An average 10-percent yield loss is estimated with present practices due to crop damage during hoeing and the presence of missed nightshade plants that compete with the crop. However, a new procedure that makes use of metam has been developed to control nightshade species in direct-seeded tomatoes in California. Metam is applied in narrow bands atop the rows which are then capped with soil. This procedure is now used on approximately 5 percent of California processing tomato acreage.

Scenarios 4, 5, and 6 (Table 39), losses of metam, of all fumigants, and of all fumigants and carbamates, would necessitate the use of napropamide and handweeding. On those acres affected, yields would decrease by 10 percent and costs would increase by $55 per acre. Scenarios 1, 2, and 3, which assume losses of 1,3-D, methyl bromide, and chloropicrin, respectively, and Scenario 7, in which only metam is available, are not expected to have impacts.

Tomatoes - Insect Control

There is no significant use of soil fumigants in tomato production for purposes of insect control.

Combined Impacts of Losses of Fumigants and Uses of Alternatives

Estimated losses due to combined effects of nematodes, plant diseases, and weeds, under the conditions of the seven individual scenarios, are shown in Tables 40-46. These tables summarize the relative importance of the soil fumigants to the crops assessed in this report and help to highlight estimated total potential impacts if they were to become unavailable. These estimates are based on the data presented in Tables 1-39. Several assumptions were required to combine the impacts of nematodes, plant diseases and weeds. These assumptions are described below.

First, total acreage of treatment with a specific fumigant was assumed to be estimated by the largest acreage treated for control of a particular pest and the acreage treated for control of the other pests were assumed to be nested within this primary acreage. Soil fumigants have a broad spectrum effect and when used for the purpose of controlling one category of pest (for example, nematodes) would result in the control of other pests (for example, fungi and weeds) as well. Therefore, acreage treated for control of various categories of pests would be nested rather than additive. For example, the acreage of potatoes in the West treated with metam was estimated as 92,000 acres because this acreage represented the largest reported acreage for control of a specific pest (nematodes, Table 15). The 47,535 acres reported treated by metam for disease control (Table 19) and the 31,000 acres reported treated for weed control (Table 17) were assumed to be included in the 92,000 acres reported treated for nematode control.

Second, yield losses were assumed to represent a range of values rather than a single value. The lowest yield loss corresponded to acreage treated for control of a single category of pest. If multiple pest control were involved, this would include those acres treated for control of the dominant pest but not treated for other pests. The maximum yield loss was determined by combining yield losses for all individual pests in multiple pest control situations. This was performed according to the method described in detail in the Methodology section of the Economic Assessment.

Third, the projected change in control cost was determined by the alternative control practice which was judged most likely to prevail in a multiple pest control situation.

Estimated effects on yields and production costs indicate that the loss of 1,3-D, Table 40, would not affect citrus seedbed or forest nursery production but would leave a range of impacts in the short term on several other crops. Four tenths of one percent of the cotton crop would sustain an estimated initial three percent decrease in yield that could escalate with time, 50 percent of field tobacco would suffer yield decreases estimated at 4 percent, and increases in production costs of \$175-\$200 per acre, and 2 percent of field citrus would have to rely on metam with no overall changes. Twelve percent of the potato acreage and 4 percent of the fresh market tomato acreage would show initial yield decreases estimated at 15 and 20 percent , respectively, with possible increases occurring with time. Seven percent of tobacco seedbed acreage, normally treated with 1,3-D, would be treated with methyl bromide, resulting in estimated yield increases of 15 to 40 percent but increasing production costs by an estimated \$175 to \$200 per acre. Tomato seedbeds would rely on methyl bromide treatments in 40 percent of its acreage with an estimated 10 percent increase in yield at an increased cost of approximately \$300 per acre. There would be no alternative available for use in 27 percent of processing tomato acreage which would show an estimated decrease of 10 percent in yields.

The loss of methyl bromide, Table 41, would force growers to make significant adjustments, particularly in seedbed maintenance. Twenty-six percent of citrus seedbeds would shift to sterile mixes (steamed soil and/or

soilless mixes) in containers, at increases of $500 per acre. There would be similar effects on tobacco seedbeds, 93 percent of which would suffer yield losses of 40 percent, eventually forcing growers to move to sterile mixes also. Tomato seedbeds and fresh tomato production would also be affected significantly. In 6 percent of the seedbeds, there would be an estimated decrease of $250 to $300 in costs per acre but yields would decrease by an estimated 20 to 32 percent. Fresh market tomatoes would show yield losses of 26 percent and production cost decreases of $100 to $150 per acre. Forest nurseries would sustain initial yield decreases of 20 percent. A very small proportion of field citrus, 0.7 percent that customarily relies on methyl bromide for tree site preparation, would show yield losses of 25 percent, escalating to 50 percent with time. No impacts are anticipated in cotton, potato, tobacco, and fresh market tomato production if methyl bromide is lost.

The loss of chloropicrin, Table 42, would result in an estimated 20 percent yield decrease in 17 percent of forest nurseries. Other crops would not be affected.

Production of potatoes and tomatoes for fresh market and for processing would be affected by the loss of metam, Table 43. Potatoes, requiring nematode, disease, and weed control, would rely on 1,3-D with estimated yield increases up to 15 percent but production costs increases by as much as $400 per acre. Metam applied by irrigation, i.e., by "chemigation" or "nemagation", is less costly and less effective than 1,3-D applied by injection. Fresh market tomatoes would show an estimated 6 percent increase in yield in 3 percent of the acreage due to the use of methyl bromide for disease control, at an increased cost of $100 to $600 per acre. In the absence of metam, napropamide and handweeding would be used for weed control, on 4 percent of the processing tomato acreage involving an estimated 10 percent loss in yield and $55 increase per acre in production costs.

Tables 44 and 45, loss of all fumigants with carbamates and organophosphates available in the former, and loss of all fumigants and carbamates, with organophosphates available in the latter, are estimated as being identical, and indicate heavy dependence on fumigants, either in terms of acreage requiring treatment and/or production cost and yield impacts.

Citrus will depend on sterile mixes, aldicarb, and fenamiphos in 26 percent of seedbeds for an estimated $500 per acre increase in production costs and, in the field, there would be an estimated 25 to 30 percent decrease in yield, possibly escalating to 50 percent with time in 0.4 percent of the acreage. Cotton would suffer an estimated 3 percent loss in 0.4 percent of its acreage.

Forest nurseries, requiring disease and weed control in 50 percent of its acreage would have no means of controlling the former and would have to rely on handweeding for the latter. As a result, forest nurseries would sustain an estimated 50 percent decrease in yield and an estimated increase in production costs of $350 to $450 per acre. The 19 percent of potato acreage that requires nematode, disease, and weed control, would be dependent on aldicarb, carbofuran, and ethoprop for nematode control, with no alternatives available for other purposes. These nonfumigant nematicides are not as efficient as the fumigants, and their use would be associated with estimated yield losses in potatoes ranging from 15 to 38 percent with losses increasing as nematode populations continue to escalate.

The loss of fumigants promises to be particularly serious in the production of tobacco and tomatoes. Tobacco seedbeds would be entirely dependent on the organophosphates and cultural practices for nematode control, sterile mixes for control of diseases, and hand labor to suppress weeds. It is anticipated that production would be forced to shift to sterile mixes that would involve an estimated $200 per acre increase in production costs. Fifty percent of field tobacco acreage requiring nematode and disease control would also have to rely on the organophosphates and on metalaxyl, projecting an estimated 4 percent decrease in yield and $110 per acre increases in production costs.

There would be similar problems in 46 percent of tomato seedbeds. Nematode control by means of ethoprop and sterile mixes would involve estimated increases in per acre production costs of $200, similar to those projected for the other seedbeds in this assessment. Field production in 52 percent of acreage devoted to fresh market tomatoes and 31 percent of acreage used for processing tomatoes would require nematode, disease, and weed control in the former, and control of nematodes and weeds in the latter. Weed control with napropamide and handweeding would be the only control measures available. Estimated losses in fresh market tomatoes would range from 10 to 66 percent, and from 10 to 19 percent in processing tomatoes.

The availability of metam, chloropicrin, and the organophosphates, as in Table 46, would involve yield losses and/or increased needs for production shifts to sterile or soilless mixes in two of the seedbed crops in this study. In citrus seedbeds, 26 percent of the acreage would sustain an estimated $500 per acre increase in production costs to support the shift to sterile mixes. All tobacco seedbeds would sustain an estimated 40-percent loss with a production shift to sterile mixes eventually. Tomato seedbeds would show yield decreases in 46 percent of its acreage estimated at 20 to 32 percent and decreases of approximately $250 to $400 per acre in production costs.

In the two tenths of one percent of the acreage of field citrus, the use of fenamiphos for nematode control and the lack of disease control capacity, would decrease yields by 25 to 30 percent that could escalate to 50 percent with time. The use of fenamiphos on four tenths of one percent of cotton acreage for nematode control would impose a 3 percent decrease in yield that could become greater in the future. Forest nurseries, restricted to the use of metam for disease and weed control, would show an estimated 20 percent yield loss in 50 percent of its acreage, and 15 percent yield losses would occur in 13 percent of potato acreage, with losses possibly escalating with time. Half of the field tobacco acreage would suffer an estimated 4 percent yield loss and an estimated increase in production costs of $110 an acre.

Field tomato production for fresh market and for processing would sustain yield decreases of 26 percent and 10 percent, respectively.

The data in Tables 39-46 emphasize several matters. A shift to sterile soil and/or soilless mixes will increase production costs. If sterility is to be maintained, plant materials will have to be maintained in containers, above, and not in contact with, soil, increasing the need for extra watering and for the use of slat and screen protective structures.

All crops, with the possible exception of cotton, rely heavily on fumigants. Seedbed production promises to be particularly hard hit.

In addition, a comparison of data in Tables 44 and 45, appears to indicate that carbamates provide little or no advantages in crop production since decreases in yields and increases in production costs appear identical whether or not they are available. In actuality, this lack of differences may indicate a lack of contingency planning, i.e., a lack in the recent past and in the present, of development of applied research programs to fit these materials for use as possible alternatives for soil fumigants. It may also be a signal that this kind of research needs to be initiated as soon as possible, in order to lessen the brunts of potential cancellations of fumigants.

Finally, yield losses and increased production costs projected for tomato seedbeds may be practical for the segment of the industry that ships tomato transplants interstate and to Canada. These growers could expect such extra costs to be acceptable to the tomato industry in the Northeast, Midwest, and Canada, which cannot do without a reliable source of transplants. However, such extra costs may render tomato seedlings too costly for local growers who do not usually have to rely on seedlings certified free of nematodes and/or plant diseases.

Table 1. Citrus pest control: acres treated, by pest, base year

Crop, by region	Planted acres, citrus	Citrus acreage by crop:			Acres treated annually	Acres treated to control:				
		Oranges	Grapefruit	Lemons		All pests	Nematodes	Weeds	Diseases	Insects
	1,000 acres					Proportion of planted acres				
East										
Seedbed	3.0	2.4	0.6	0.0	1.1	35.00%	14.00%	0.0%	35.00%	0.0%
Field	668.0	542.0	126.0	0.0	0.5	0.07%	0.07%	0.0%	0.07%	0.0%
West										
Seedbed	2.2	1.0	0.9	0.3	0.3	13.00%	12.70%	0.0%	12.00%	0.0%
Field	358.0	215.0	71.0	72.0	3.6	1.00%	1.00%	0.0%	0.00%	0.0%
Both regions										
Seedbed	5.2	3.4	1.5	0.3	1.4	25.70%	13.50%	0.0%	25.30%	0.0%
Field	1,026.0	757.0	197.0	72.0	4.1	0.40%	0.40%	0.0%	0.05%	0.0%

Table 2. Citrus nematode control, base year: acres treated, application and cost data

Fumigant	Acres treated	Application data: Method	Frequency	Rate	Cost/acre
East					
Methyl bromide					
Seedbed	420	injection	1	650#	$600
Field	500	injection	1	100# a/	$150
West					
Methyl bromide					
Seedbed	140	gas pressure	1	350-450#	$1,000
Field	NA	NA		NA	NA
1,3-D					
Seedbed	0	NA		NA	NA
Field	1,800	injection	1	25-35 gallons	$250-$325
Metam					
Seedbed	NA	NA		NA	NA
Field	1,800	irrigation	1	5-10 gallons	$100
Methyl bromide +chloropicrin					
Seedbed	140	gas pressure	1	350-450#	$1,000
Field	NA	NA		NA	NA
Region					
Seedbed	280				$1,000
Field	3,600				$193

a/ Treatments are applied to tree sites only, at rate of 1.5 pounds per site. The area between tree sites is not treated. This treatment provides the same fumigant concentration in the tree sites that would have been injected into the soil if an acre had been treated overall with 650 pounds.

Table 3. Citrus nematode control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice							
Seedbed	NA	greenhouse sterile mixes	NA	NA	greenhouse sterile mixes	greenhouse sterile mixes	greenhouse sterile mixes
Field	NA	1,3-D	NA	NA	aldicarb	fenamiphos	fenamiphos
Projected change in yield (%)							
Seedbed	NA	+1%	NA	NA	+1%	+1%	+1%
Field	NA	0%	NA	NA	0%	0%	0%
Projected change in control costs/acre							
Seedbed	NA	+$500	NA	NA	+$500	+$500	+$500
Field	NA	$0	NA	NA	$0	$0	$0
West							
Alternative control practice							
Seedbed	no impact	1,3-D	NA	NA	organo-phosphates carbamates	organo-phosphates carbamates	organo-phosphates carbamates
Field	metam	NA	NA	1,3-D	aldicarb	fenamiphos	fenamiphos
Projected change in yield (%)							
Seedbed	NA	-80%	NA	NA	-80%	-80%	-80%
Field	0%	NA	NA	0%	-30%	-30%	-30%
Projected change in control costs/acre							
Seedbed	NA	-$900	NA	NA	-$900	-$900	-$900
Field	$0	NA	NA	$0	$0	$0	$0

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination is lost. All other fumigants plus alternatives available, as in item 1). 4) Metam is lost. All other fumigants plus alternative are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 4. Citrus disease control, base year use: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
East					
Methyl bromide					
Seedbed	0	NA	NA	NA	NA
Field	500	injection	1	100#	$400
Methyl bromide +Chloropicrin					
Seedbed	1,050	injection	1	300#	$500
Field	0	NA	NA	NA	NA
Region					
Seedbed	1,050				$500
Field	500				$400
West					
Methyl bromide +Chloropicrin					
Seedbed	272	injection	1	300#	$500
Field	0	NA	NA	NA	NA

Table 5. Citrus disease control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice							
Seedbed	NA	metam	NA	NA	soilless mix	soilless mix	metam
Field	NA	none	NA	NA	none	none	none
Projected change in yield(%)							
Seedbed	NA	-3%	NA	NA	+1%	+1%	-5%
Field	NA	-25%	NA	NA	-25%	-25%	-25%
Projected change in control costs							metam
Seedbed	NA	$0	NA	NA	+$500	+$500	-$200
Field	NA	-$400	NA	NA	-$400	-$400	-$400
West							
Alternative control practice							
Seedbed	NA	soilless mix	NA	NA	soilless mix	soilless mix	metam
Field	NA	NA	NA	NA	NA	NA	NA
Projected change in yield (%)							
Seedbed	NA	+7%	NA	NA	+7%	+7%	-5%
Field	NA	NA	NA	NA	NA	NA	NA
Projected change in control costs/acre							
Seedbed	NA	+$500	NA	NA	+$500	+$500	$0
Field	NA	NA	NA	NA	NA	NA	NA

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.

a/ The seven scenarios are defined as follows: 1)1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly,and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly,and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 6. Cotton pest control: acres treated, by pest, base year

Crop, by region	Planted acres	Acres treated	Acres treated to control:				
			All pests	Nematodes	Weeds	Diseases	Insects
	1,000	1,000	------------ Proportion of planted acres -------------				
East	2,893	6.0	0.21%	0.20%	0.00%	0.00%	0.00%
West	7,174	36.0	0.50%	0.50%	0.00%	0.00%	0.00%
Both regions	10,067	42.5	0.42%	0.42%	0.00%	0.00%	0.00%

Table 7. Cotton nematode control, base year: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
East					
1,3-D	6,000	injection	1	3-5 gallons	$40
1,3-D + MIC	500	injection	1	3-5 gallons	$40
Region	6,500	-	-	-	$40
West					
1,3-D	36,000	injection	1	6-10 gallons	$80

Table 8. Cotton nematode control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice	aldicarb, crop rotation, resistant varieties, plowing	NA	NA	NA	aldicarb, crop rotation, resistant varieties, plowing	fenamiphos	fenamiphos
Projected change in yield (%)	0%	NA	NA	NA	0%	-3%	-3%
Projected change in control costs/acre	$0	NA	NA	NA	$0	-$13	-$13
West							
Alternative control practice	aldicarb, crop rotation	NA	NA	NA	aldicarb, crop rotation	fenamiphos, crop rotation	fenamiphos, crop rotation
Projected change in yield (%)	-3%	NA	NA	NA	-3%	-3%	-3%
Projected change in control costs/acre	-$13	NA	NA	NA	-$13	-$13	-$13

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigant are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 9. Forest nursery pest control: acres treated, by pest, base year

Crop, by region	Planted acres in production	Acres treated each year a/	Acres treated to control:				
			All pests	Nematodes	Weeds	Diseases	Insects
			----------- Proportion of planted acres -------------				
North	3,495	820	23%	0%	23%	23%	0%
South	2,035	1,950	96%	0%	96%	96%	0%
Both regions	5,530	2,770	50%	0%	50%	50%	0%

a/ Acres treated in the North Region are treated on a 3 to 4 year rotation. Most acres in production are treated during the rotation. Acres treated in the South Region are treated on a 1 to 2 year rotation. Most acres in production are treated during the rotation.

Table 10. Forest nursery weed control, base year: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
North					
Methyl bromide	105	injection	1	350#	$950
Methyl bromide +Chloropicrin	715	injection	1	400#	$950
Region	820				$950
South					
Methyl bromide	1,365	injection	1	350#	$950
Methyl bromide +Chloropicrin	585	injection	1	300#	$900
Region	1,950				$935

Table 11. Forest nursery weed control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
North							
Alternative control practice	NA	metam	NA	NA	handweeding	handweeding	metam
Projected change in yield (%)	NA	-20%	NA	NA	-50%	-50%	-20%
Projected change in control costs/acre	NA	-$150	NA	NA	+$350	+$350	-$200
South							
Alternative control practice	NA	metam	NA	NA	handweeding	handweeding	metam
Projected change in yield (%)	NA	-20%	NA	NA	-50%	-50%	-20%
Projected change in control costs/acre	NA	-$200	NA	NA	+$450	+$450	-$250

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 12. Forest nursery disease control, base year: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
North					
Methyl bromide	105	injection	1	350#	$950
Methyl bromide +Chloropicrin	715	injection	1	400#	$950
Region	820				$950
South					
Methyl bromide	1,365	injection	1	350#	$950
Methyl bromide +Chloropicrin	585	injection	1	300#	$900
Region	1,950				$935

Table 13. Forest nursery disease control projections, scenario 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
North							
Alternative control practice	NA	1,3-D, metam	1,3-D, metam	NA	none	none	metam
Projected change in yield(%)	NA	-20%	-20%	NA	-50%	-50%	-20%
Projected change in control costs/acre	NA	-$100	-$150	NA	-$950	-$950	-$100
South							
Alternative control practice	NA	1,3-D, metam	1,3-D, metam	NA	none	none	metam
Projected change in yield(%)	NA	-20%	-20%	NA	-50%	-50%	-20%
Projected change in control costs/acre	NA	-$150	-$175	NA	-$950	-$950	-$150

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.

None = no available alternative

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 14. Potatoes pest control: acres treated, by pest, base year

Crop, by region	Planted acres	Acres treated	Acres treated to control:				
			All pests	Nematodes	Weeds	Diseases	Insects
	1,000	1,000	---------- Proportion of planted acres ---------				
East	273	13	5%	4%	0%	5%	0%
West	1,031	238	23%	23%	3%	6%	0%
Both regions	1,304	251	19%	19%	2%	6%	0%

Table 15. Potatoes nematode control, base year use: acres treated, application data

Fumigant	Acres treated	Application data: Method	Frequency	Rate	Cost/acre
East 1,3-D	10,600	chisel injected, row and broadcast	1	20 gallons	$225
West 1,3-D	133,000	chisel injected, row and broadcast	1	15-20 gallons	$168-$225
Metam	92,000	irrigation broadcast	1	50 gallons	$275
1,3-D +MIC	12,800	chisel injected, row and broadcast	1	20 gallons	$225
Region	237,800				$243

Table 16. Potatoes nematode control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice	metam	NA	NA	NA	carbofuran, aldicarb, ethoprop	ethoprop	metam, ethoprop
Projected change in yield (%)	-15%	NA	NA	NA	-15%	-15%	-15%
Projected change in control costs/acre	+$50	NA	NA	NA	+$50	+$50	+$50
West							
Alternative control practice	metam	NA	NA	1,3-D	carbofuran, aldicarb, ethoprop	ethoprop	metam, ethoprop
Projected change in yield (%)	-15%	NA	NA	+15%	-15%	-15%	-15%
Projected change in control costs/acre	+$50	NA	NA	-$50	+$50	+$50	+$50

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 17. Potatoes weed control, base year use: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
West					
Metam	31,000	irrigation	1	50 gallons	$250

Table 18. Potatoes weed control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
West							
Alternative control practice	NA	NA	NA	none	none	none	NA
Projected change in yield (%)	NA	NA	NA	-2%	-2%	-2%	NA
Projected change in control costs/acre	NA	NA	NA	-$250	-$250	-$250	NA

NA = Not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.
None = No available alternatives.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 19. Potatoes disease control, base year: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
East					
Metam	13,348	irrigation	1	42 gallons	$263
West					
1,3-D + MIC	11,185	injection	1	50 gallons	$800
Metam	47,535	irrigation	1	60 gallons	$375
Region	58,720				$456

Table 20. Potatoes disease control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice	NA	NA	NA	1,3-D mixtures	none	none	metam
Projected change in yield (%)	NA	NA	NA	0%	-25%	-25%	0%
Projected change in control costs/acre	NA	NA	NA	+$377	-$263	-$263	NA
West							
Alternative control practice	metam	NA	NA	1,3-D mixtures	none	none	metam
Projected change in yield (%)	0%	NA	NA	0%	-25%	-25%	0%
Projected change in control costs/acre	-$425	NA	NA	+$425	-$456	-$456	-$425

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.
None = no available alternatives.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 21. Tobacco pest control: acres treated, by pest, base year

Crop, by region	Planted acres	Acres treated	Acres treated to control:				
			All pests	Nematodes	Weeds	Diseases	Insects
	1,000	1,000	Proportion of planted acres				
East							
Seedbed	14.0	14.0	100%	100%	100%	100%	0%
Field	833.0	416.5	50%	50%	0%	7%	0%
West							
Seedbed	0.0	0.0	0%	0%	0%	0%	0%
Field	0.0	0.0	0%	0%	0%	0%	0%
Both regions							
Seedbed	14.0	14.0	100%	100%	100%	100%	0%
Field	833.0	416.5	50%	50%	0%	7%	0%

Table 22. Tobacco nematode control, base year: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
East					
Methyl bromide					
Seedbed	10,287	injected	1	435#	$925
Field	0	NA	NA	NA	NA
1,3-D					
Seedbed	0	NA	NA	NA	NA
Field	326,850	injected	1	5 gal.	$80
Methyl bromide +Chloropicrin					
Seedbed	1,880	injected	1	300 gal.	$800
Field	0	NA	NA	NA	NA
1,3-D +MIC					
Seedbed	1,731	injected	1	35 gal.	$750
Field	88,883	injected	1	7.5 gal.	$113
Region					
Seedbed	13,898				$886
Field	415,733				$87

Table 23. Tobacco nematode control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice							
Seedbed	methyl bromide	metam 1,3-D mixture	NA	NA	ethoprop, fenamiphos resistant var. crop rotation, deep plowing	ethoprop, fenamiphos resistant var. crop rotation, deep plowing	metam
Field	fenamiphos, fallow, resistant var.	NA	NA	NA	ethoprop, fenamiphos resistant var. crop rotation, deep plowing	ethoprop, fenamiphos resistant var. crop rotation, deep plowing	ethoprop, fenamiphos resistant var. crop rotation deep plowing
Projected change in yield(%)							
Seedbed	+40%	-40%	NA	NA	-40%	-40%	-40%
Field	-4%	NA	NA	NA	-4%	-4%	-4%
Projected change in control costs/acre							metam
Seedbed	+$175	-$175	NA	NA	-$800	-$800	-$175
Field	+$110	NA	NA	NA	+$110	+$110	+$110

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 24. Tobacco weed control, base year: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
East					
Methyl bromide					
Seedbed	13,020	broadcast	1	1.5 # per 150 sq. ft	$1,000
Field	0	NA	NA	NA	NA
1,3-D + MIC					
Seedbed	980	broadcast	1	10 ounces per 100 sq. ft.	$750
Field	0	NA	NA	NA	NA
Region					
Seedbed	14,000				$983
Field	0				NA

Table 25. Tobacco weed control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice							
Seedbed	NA	metam or 1,3-D mixture + handweeding	NA	NA	handweeding	handweeding	metam + handweeding
Field	NA	NA	NA	NA	NA	NA	NA
Projected change in yield (%)							
Seedbed	NA	0%	NA	NA	0%	0%	0%
Field	NA	NA	NA	NA	NA	NA	NA
Projected change in control costs/acre							
Seedbed	NA	$0 b/	NA	NA	$0 b/	$0 b/	$0 b/
Field	NA	NA	NA	NA	NA	NA	NA

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

b/ The elimination of methyl bromide offsets handweeding cost.

Table 26. Tobacco disease control, base year: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
East					
Methyl bromide					
Seedbed	11,845	broadcast chisel-injected	1	9# per 100sq.yds	$1,000
Field	0	NA	NA	NA	NA
Methyl bromide +Chloropicrin					
Seedbed	1,901	broadcast chisel-injected	1	10# per 100sq.yds	$1,000
Field	0	NA	NA	NA	NA
1,3-D +MIC					
Seedbed	254	injected	1	8# per 100sq.yds	$750
Field	54,340	soil-injected gravity flow	1	13 gal. per acre	$280
Region					
Seedbed	14,000				$995
Field	54,340				$280

Table 27. Tobacco disease control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice							
Seedbed	soilless mix	soilless mix	NA	NA	soilless mix	soilless mix	soilless mix
Field	metalaxyl	NA	NA	NA	metalaxyl	metalaxyl	metalaxyl
Projected change in yield(%)							
Seedbed	+15%	+15%	NA	NA	+15%	+15%	+15%
Field	0%	NA	NA	NA	0%	0%	0%
Projected change in control cost/acre							
Seedbed	+$200	+$200	NA	NA	+$200	+$200	+$200
Field	-$180	NA	NA	NA	-$180	-$180	-$180

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 28. Tomatoes (fresh market) pest control: acres treated, by pest, base year

Crop, by region	Planted acres	Acres treated	Acres treated to control: All pests	Nematodes	Weeds	Diseases	Insects
	1,000	1,000	------------ Proportion of planted acres				------------
East							
Seedbed a/	6.5	5.5	46%	46%	0%	39%	0%
Field	94.0	59.2	63%	61%	58%	63%	0%
West							
Seedbed	0.0	0.0	0%	0%	0%	0%	0%
Field	33.8	3.0	9%	8%	0%	9%	0%
Both regions							
Seedbed	6.5	5.5	46%	46%	0%	39%	0%
Field	127.8	62.2	49%	47%	43%	49%	0%

a/ Includes approximately 3,000 acres in Georgia that produce transplants used to grow processing tomatoes in the Northeast, Ohio, Michigan, and Canada. Treatment is preplant with ethoprop, a nonfumigant organophosphate nematicide.

Table 29. Tomatoes (fresh market) nematode control, base year: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
East					
Methyl bromide +Chloropicrin					
Seedbed	400	injected	1	350#	$1,000
Field	57,200	injected	1	350#	$500 a/
1,3-D +MIC					
Seedbed	2,600	injected	1	15 gal.	$700
Field	75	injected	1	10 gal.	$350 a/
Region					
Seedbed	3,000				$740
Field	57,275				$500 a/
West					
Methyl bromide					
Seedbed	0	NA	NA	NA	NA
Field	900	injected	1	400#	$850
1,3-D					
Seedbed	0	NA	NA	NA	NA
Field	1,800	injected	1	10 gal.	$100
Region					
Seedbed	0				0
Field	2,700				$350

a/ Application is at same concentration as an overall treatment, but it is applied in the row only.

Table 30. Tomatoes (fresh market) nematode control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice							
Seedbed	methyl bromide	1,3-D mixture	NA	NA	ethoprop	ethoprop	metam
Field	methyl bromide	1,3-D mixture	NA	NA	none	none	metam
Projected change in yield(%)							
Seedbed	+10%	-20%	NA	NA	-20%	-20%	-20%
Field	+20%	-20%	NA	NA	-60%	-60%	-20%
Projected change in control cost/acre							
Seedbed	+$300	-$300	NA	NA	-$400	-$400	-$400
Field	+$150	-$150	NA	NA	-$500	-$500	-$50
West							
Alternative control practice							
Seedbed	NA	NA	NA	NA	NA	NA	NA
Field	oxamyl	1,3-D	NA	NA	cultural	cultural	chloropicrin
Projected change in yield (%)							
Seedbed	NA	NA	NA	NA	NA	NA	NA
Field	-20%	-30%	NA	NA	-20%	-20%	0%
Projected change in control costs/acre							
Seedbed	NA	NA	NA	NA	NA	NA	NA
Field	$0	-$750	NA	NA	-$275	-$275	$0

NA = Not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.
None = No available alternatives.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 31. Tomatoes (fresh market) weed control, base year: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
East					
Methyl bromide					
Seedbed	0	NA	NA	NA	NA
Field	4,700	in row	1	200#	$485
Methyl bromide +Chloropicrin					
Seedbed	0	NA	NA	NA	NA
Field	48,880	in row	1	200#	$500
1,3-D + MIC					
Seedbed	0	NA	NA	NA	NA
Field	940	in row	1	20 gal.	$320
Region					
Seedbed	0				$0
Field	54,520				$496

Table 32. Tomatoes (fresh market) weed control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice							
Seedbed	NA	NA	NA	NA	NA	NA	NA
Field	NA	napropamide + handweeding	NA	NA	napropamide + handweeding	napropamide + handweeding	napropamide + handweeding
Projected change in yield (%)							
Seedbed	NA	NA	NA	NA	NA	NA	NA
Field	NA	0%	NA	NA	0%	0%	0%
Projected change in control cost/acre							
Seedbed	NA	NA	NA	NA	NA	NA	NA
Field	NA	$0 b/	NA	NA	$0 b/	$0 b/	$0 b/

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

b/ Lower cost of alternative chemical offsets handweeding cost.

Table 33. Tomatoes (fresh market) disease control, base year: acres treated application data

Fumigant	Acres treated	Application data: Method	Frequency	Rate	Cost/acre
East					
Methyl bromide					
Seedbed	54	injected	1	300#	$600
Field	1,500	injected	1	283#	$575
Metam					
Seedbed	0	NA	NA	NA	NA
Field	650	injected	1	90 gal.	$600
Methyl bromide +Chloropicrin					
Seedbed	70	injected	1	250#	$500
Field	53,975	injected	1	283#	$550
1,3-D + MIC					
Seedbed	2,430	injected	1	40 gal.	$680
Field	2,765	injected	1	20 gal.	$320
Region					
Seedbed a/	2,554				$673
Field	58,890				$540
West					
Metam					
Seedbed	0	NA	NA	NA	NA
Field	2,700	irrigat.	1	60 gal.	$400
Methyl bromide +Chloropicrin					
Seedbed	0	NA	NA	NA	NA
Field	435	injected	1	250#	$1,000
Region					
Seedbed	0				$0
Field	3,135				$483

a/ Approximately 3,000 additional acres are treated preplant with ethoprop, a nonfumigant organophosphate nematicide.

Table 34. Tomatoes (fresh market) disease control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice							
Seedbed	NA	metam	NA	NA	none	none	metam
Field	NA	metam	NA	MC-33	none	none	metam
Projected change in yield (%)							
Seedbed	NA	-15%	NA	NA	-30%	-30%	-15%
Field	NA	-7%	NA	+7%	-14%	-14%	-7%
Projected change in control cost/acre							
Seedbed	NA	-$250	NA	NA	-$650	-$650	-$250
Field	NA	-$50	NA	+$100	-$300	-$300	-$50
West							
Alternative control practice							
Seedbed	NA	NA	NA	NA	NA	NA	NA
Field	NA	metam	NA	MC-33	none	none	metam
Projected change in yield (%)							
Seedbed	NA	NA	NA	NA	NA	NA	NA
Field	NA	-6%	NA	+6%	-10%	-10%	-6%
Projected change in control costs/acre							
Seedbed	NA	NA	NA	NA	NA	NA	NA
Field	NA	-$600	NA	+$600	-$500	-$500	-$600

NA = Not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.
None = No available alternatives.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 35. Tomatoes (processing market) pest control: acres treated, by pest, base year

Crop, by region	Planted acres	Acres treated	Acres treated to control:				
			All pests	Nematodes	Weeds	Diseases	Insects
	1,000	1,000	------------ Proportion of planted acres ---------------				
East	59.0	0.0	0%	0%	0%	0%	0%
West	248.0	81.8	33%	33%	5%	0%	0%
Both regions	307.0	81.8	27%	27%	4%	0%	0%

Table 36. Tomatoes (processing market) nematode control, base year: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
West					
1,3-D	83,000	injection, cultipac	1	10 gallons	$100

Table 37. Tomatoes (processing market) nematode control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
East							
Alternative control practice	NA	NA	NA	NA	NA	NA	NA
Projected change in yield (%)	NA	NA	NA	NA	NA	NA	NA
Projected change in control costs/acre	NA	NA	NA	NA	NA	NA	NA
West							
Alternative control practice	none	NA	NA	NA	none	none	none
Projected change in yield (%)	-10%	NA	NA	NA	-10%	-10%	-10%
Projected change in control costs/acre	-$100	NA	NA	NA	-$100	-$100	-$100

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.
None = no available alternatives.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 38. Tomatoes (processing market) weed control, base year: acres treated, application data

Fumigant	Acres treated	Application data:			
		Method	Frequency	Rate	Cost/acre
West					
Metam	12,400	band	1	7.5 gallons	$50

Table 39. Tomatoes (processing market) weed control projections, scenarios 1-7 a/

Projection of:	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
West							
Alternative control practice	NA	NA	NA	napropamide + handweeding	napropamide + handweeding	napropamide + handweeding	NA
Projected change in yield (%)	NA	NA	NA	-10%	-10%	-10%	NA
Projected change in control costs/acre	NA	NA	NA	+$55	+$55	+$55	NA

NA = Not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) is not registered for indicated use.

a/ The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 40. Present use of 1,3-D in production of citrus, cotton, forest nurseries, potatoes, tobacco, and tomatoes and the impacts of its potential loss on these crops (Scenario 1).a/

	Present fumigant usage			Response if fumigant unavailable			
	Acres treated			Alternatives for control of			
Crop	% of total acres planted	Acres	Pests[b/] requiring treatment	Nematodes	Diseases	Weeds	Impact on acres treated
Citrus seedbed	0	0	-	-	-	-	-
Citrus field	0.2[c/]	1,800	N	metam	-	-	None
Cotton field	0.4	42,500	N	aldicarb, cultural	-	-	3% yield loss initially, possibly escalating in future.
Forest nursery	0	0	-	-	-	-	-
Potato field	12	156,400	N,D	metam	metam	-	15% yield loss initially, escalating in future.
Tobacco seedbed	7	988	N,D	methyl bromide	sterile mix	-	15-40% yield increase, $175-200 production cost increase per acre.
Tobacco field	50	415,733	N,D	fenamiphos, cultural	metalaxyl	-	4% yield loss, $110 production cost increase per acre.
Tomato seedbed	40	2,600	N	methyl bromide	-	-	10% yield increase, $300 production cost increase per acre.
Tomato fresh	4	4,565	N	oxamyl	-	-	20% yield loss initially, escalating in future.
Tomato processing	27	83,000	N	none	-	-	10% yield loss

a/ The estimates of 1,3-D usage reflect the availability of this fumigant from domestic and imported sources.
b/ N = nematode, D = disease, W = weed.
c/ This acreage represents 7% of the total acres planted annually.

Table 41. Present use of methyl bromide in production of citrus, cotton, forest nurseries, potatoes, tobacco, and tomatoes and the impacts of its potential loss on these crops (Scenario 2).

	Present fumigant usage			Response if fumigant unavailable			
	Acres treated			Alternatives for control of			
Crop	% of total acres planted	Acres	Pests[a/] requiring treatment	Nematodes	Diseases	Weeds	Impact on acres treated
Citrus seedbed	26.0	1,330	N,D	sterile mix, 1,3-D	sterile mix, metam	-	Production shift to sterile mixes eventually, $500 production cost increase per acre.
Citrus field	0.05[b/]	500	N,D	1,3-D	none	-	25% yield loss initially, escalating to 50% loss.
Cotton field	0	0	-	-	-	-	
Forest nursery	50	2,770	D,W	-	metam 1,3-D	metam	20% yield loss
Potato field	0	0	-	-	-	-	-
Tobacco seedbed	93	12,978	N,D,W	1,3-D	sterile mix	metam, handweed	40% yield loss, production shift to sterile mixes eventually.
Tobacco field	0	0	-	-	-	-	-
Tomato seedbed	6	400	N,D	1,3-D	metam	-	20-32% yield loss, $250-300 production cost decrease per acre.
Tomato fresh	45	58,100	N,D,W	1,3-D	metam	napropamide, handweed	26% yield loss, $100-150 production cost decrease per acre.
Tomato processing	0	0	-	-	-	-	-

a/ N = nematode, D = disease, W = weed.
b/ This acreage represents 2% of the total acres planted annually.

Table 42. Present use of chloropicrin in production of citrus, cotton, forest nurseries, potatoes, tobacco, and tomatoes and the impacts of its potential loss on these crops (Scenario 3).

	Present fumigant usage			Response if fumigant unavailable			
	Acres treated			Alternatives for control of			
Crop	% of total acres planted	Acres	Pests[a/] requiring treatment	Nematodes	Diseases	Weeds	Impact on acres treated
Citrus seedbed	0	0	-	-	-	-	-
Citrus field	0	0	-	-	-	-	-
Cotton field	0	0	-	-	-	-	-
Forest nursery	47	1,300	D	-	1,3-D, metam	-	20% yield loss
Potato field	0	0	-	-	-	-	-
Tobacco seedbed	0	0	-	-	-	-	-
Tobacco field	0	0	-	-	-	-	-
Tomato seedbed	0	0	-	-	-	-	-
Tomato fresh	0	0	-	-	-	-	-
Tomato processing	0	0	-	-	-	-	-

a/ N = nematode, D = disease, W = weed.

Table 43. Present use of metam in production of citrus, cotton, forest nurseries, potatoes, tobacco, and tomatoes and the impacts of its potential loss on these crops (Scenario 4).

Crop	Present fumigant usage: Acres treated: % of total acres planted	Acres	Pests[a/] requiring treatment	Response if fumigant unavailable: Alternatives for control of: Nematodes	Diseases	Weeds	Impact on acres treated
Citrus seedbed	0	0	-	-	-	-	-
Citrus field	0.2[b/]	1,800	N	1,3-D	-	-	None
Cotton field	0	0	-	-	-	-	-
Forest nursery	0	0	-	-	-	-	-
Potato field	8	105,348	N,D,W	1,3-D	1,3-D	none	Up to 15% yield increase, $50 lower to $400 higher production cost per acre.
Tobacco seedbed	0	0	-	-	-	-	-
Tobacco field	0	0	-	-	-	-	-
Tomato seedbed	0	0	-	-	-	-	-
Tomato fresh	3	3,350	D	-	methyl bromide	-	6% yield increase, $100-600 production cost increase per acre.
Tomato processing	4	12,400	W	-	-	napropamide, handweed	10% yield loss, $55 production cost increase per acre.

a/ N = nematode, D = disease, W = weed.
b/ This acreage represents 7% of the total acres planted annually.

Table 44. Present use of all fumigants in production of citrus, cotton, forest nurseries, potatoes, tobacco, and tomatoes and the impacts of their potential loss on these crops (Scenario 5).

Crop	Present fumigant usage: Acres treated: % of total acres planted	Acres	Pests[a/] requiring treatment	Response if fumigant unavailable: Alternatives for control of: Nematodes	Diseases	Weeds	Impact on acres treated
Citrus seedbed	26	1,330	N,D	sterile mix, aldicarb, fenamiphos	sterile mix	-	Production shift to sterile mixes, $500 production cost increase per acre.
Citrus field	0.4[b/]	4,100	N,D	aldicarb	none	-	25-30% yield loss, escalating to 50%.
Cotton field	0.4	42,500	N	aldicarb, cultural	-	-	3% yield loss, possibly escalating in future.
Forest nursery	50	2,770	D,W	-	none	handweed	50% yield loss, $350-450 production cost increase per acre.
Potato field	20	261,748	N,D,W	carbofuran, aldicarb, ethoprop	none	none	15-38% yield loss, escalating in future.
Tobacco seedbed	100	14,000	N,D,W	ethoprop, fenamiphos, cultural	sterile mix	handweed	Production shift to sterile mixes, $200 production cost increase per acre.
Tobacco field	50	415,733	N,D	ethoprop, fenamiphos, cultural	metalaxyl	-	4% yield loss, $110 production cost increase per acre.
Tomato seedbed	46	3,000	N,D	ethoprop	none	-	Production shift to sterile mixes, $200 production cost increase per acre.
Tomato fresh	52	66,015	N,D,W	cultural	none	napropamide, handweed	10-66% yield loss
Tomato processing	31	95,400	N,W	none	-	napropamide, handweed	10-19% yield loss

a/ N = nematode, D = disease, W = weed.
b/ This acreage represents 15% of the total acres planted annually.

Table 45. Present use of all fumigants and three carbamates in production of citrus, cotton, forest nurseries, potatoes, tobacco, and tomatoes and the impacts of their potential loss on these crops (Scenario 6).

Crop	Present fumigant usage: Acres treated: % of total acres planted	Acres	Pests[a/] requiring treatment	Response if fumigant unavailable: Alternatives for control of: Nematodes	Diseases	Weeds	Impact on acres treated
Citrus seedbed	26	1,330	N,D	sterile mix, fenamiphos	sterile mix	-	Production shift to sterile mixes, $500 production cost increase per acre.
Citrus field	0.4[b/]	4,100	N,D	fenamiphos	none	-	25-30% yield loss, escalating to 50%.
Cotton field	0.4	42,500	N	fenamiphos, cultural	-	-	3% yield loss, possibly escalating in future.
Forest nursery	50	2,770	D,W	-	none	handweed	50% yield loss, $350-450 production cost increase per acre.
Potato field	20	261,748	N,D,W	ethoprop	none	none	15-38% yield loss, escalating in future.
Tobacco seedbed	100	14,000	N,D,W	ethoprop, fenamiphos, cultural	sterile mix	handweed	Production shift to sterile mixes, $200 production cost. increase per acre.
Tobacco field	50	415,733	N,D	ethoprop, fenamiphos, cultural	metalaxyl	-	4% yield loss, $110 production cost increase per acre.
Tomato seedbed	46	3,000	N,D	ethoprop	none	-	Production shift to sterile mixes, $200 production cost increase per acre.
Tomato fresh	52	66,015	N,D,W	cultural	none	napropamide, handweed	10-66% yield loss
Tomato processing	31	95,400	N,W	none	-	napropamide, handweed	10-19% yield loss

a/ N = nematode, D = disease, W = weed.

b/ This acreage represents 15% of the total acres planted annually.

Table 46. Present use of 1,3-D and methyl bromide in production of citrus, cotton, forest nurseries, potatoes, tobacco, and tomatoes and the impacts of availability of metam, chloropicrin, and three organophosphates only on these crops (Scenario 7).

	Present fumigant usage			Response if fumigant unavailable			
	Acres treated			Alternatives for control of			
Crop	% of total acres planted	Acres	Pests[a/] requiring treatment	Nematodes	Diseases	Weeds	Impact on acres treated
Citrus seedbed	26	1,330	N,D	sterile mix, fenamiphos	metam	-	Production shift to sterile mixes eventually, $500 production cost increase per acre.
Citrus field	0.2[b/]	2,300	N,D	fenamiphos	none	-	25-30% yield loss, escalating to 50%.
Cotton field	0.4	42,500	N	fenamiphos, cultural	-	-	3% yield loss, possibly escalating in future.
Forest nursery	50	2,770	D,W	-	metam	metam	20% yield loss
Potato field	12	156,400	N,D	metam, ethoprop	metam	-	15% yield loss, escalating in future.
Tobacco seedbed	100	14,000	N,D,W	metam	sterile mix	metam, handweed	40% yield loss, production shift to sterile mixes eventually.
Tobacco field	50	415,733	N,D	ethoprop, fenamiphos	metalaxyl	-	4% yield loss, $110 production cost increase per acre.
Tomato seedbed	46	3,000	N,D	metam, ethoprop	metam	-	20-32% yield loss, $250-400 production cost decrease per acre.
Tomato fresh	49	62,665	N,D,W	metam, chloropicrin	metam	napropamide, handweed	26% yield loss
Tomato processing	27	83,000	N	none	-	-	10% yield loss

a/ N = nematode, D = disease, W = weed.
b/ This acreage represents 7.0% of the total acres planted annually.

ECONOMIC ASSESSMENT OF SOIL FUMIGANTS

The economic assessment in this section uses estimates of how all soil-borne pests would act during a growing season to affect crop yields, as each regulatory scenario with its set of control practices, allowable chemicals, treated acreage, and control costs is considered. The combined estimates of how all pests would act together are derived according to the methodology explained in Appendix A. The assessment appraises short-run impacts on both crop producers and consumers.

Method of Economic Analysis

The economic analysis in this report is short-run in nature. That is, the economic outcome of a scenario action is assumed to be an alternative outcome to the base year situation, or what would have happened had base case fumigant use been replaced by an alternative pattern of fumigant use specified by a scenario action. However, a different, but acceptable way to look at the alternative outcome is to assume that, absent any scenario action, the base year situation would simply repeat itself in the following year, and that, given any of the seven scenario actions, each alternative outcome would also occur one year following the base year. The short-run economic analysis flows from the earlier short-run biological analysis, which centered upon the impacts on crop yields (after one growing season) of changes in the kinds of fumigants and other chemicals used to control soil-borne pests.

Nevertheless, the short-run analytical method in this report has the obvious limitation of not analyzing potential long-term effects of any of the seven alternative scenario actions to regulate fumigants. In some cases, the

biological section has noted the potential for major long-run biological effects on certain crops, such as citrus fruit and tree-farm trees, but has not attempted to quantify such potential long-term biological effects.

Estimating the impact on producers--The first step is to estimate the change from the base year situation in the total cost of controlling soil-borne pests, by crop, for each scenario. The change in total control cost, by crop, (Table 49) is calculated by multiplying the change in control cost per acre (Table 48) by the number of acres treated (derived from Table 47).

The second step is to estimate the total farm value of production, by crop, for each scenario. To make this estimate, several preparatory calculations are required. One of these appears in Table 52, in which total physical unit production, by crop, for each scenario is estimated by multiplying the projected yield per acre on planted acres (Table 51) by the crop planted acreage (Table 47). Another of these calculations appears in Table 53, in which the price elasticity of demand for each crop is used to estimate the projected new (alternative) farm price per unit which occurs when total production changes as shown in Table 52. The price elasticity values in Table 53 are derived as explained in Appendix B, and are used to calculate the projected prices received by farmers also shown in Table 53. The final preparatory calculation appears in Table 54, in which total value of production, by crop and by scenario, is estimated by multiplying a crop`s production (from Table 52) by the crop`s price (from Table 53).

The third step is to estimate the net change in revenue to producers--change from the base situation--by crop and regulatory scenario. This net change

(Table 55) is the combined result of change in costs and change in total revenue. This change is a "partial budget" concept, under which only those changes in costs and revenues which are attributable to fumigant use and other control of soil-borne pests are considered. The net change in revenue to producers is calculated by combining the change in control cost (Table 49) with the dollar change from the base year in total farm value of production (calculated from Table 54), by crop and scenario.

The final step is to provide an estimate of the magnitude of the dollar impact on producers of a crop. The magnitude of the financial impact is measured by percentages showing net revenue change as a percentage of crop value.

Estimating the impact on consumers--The crops included in this fumigant study may reach the consumer with no or minimal processing, as in the case of fresh citrus, potatoes, and tomatoes, or with considerable processing, as in the case of cotton clothing, frozen concentrated orange juice, cigarettes, or canned tomatoes. But there are also other processed products which come from the crops studied. In order to make this analysis manageable, one major-use product processed from a given crop is allowed to stand as a proxy for other processed products from the same crop.

The analysis focuses on what would happen under each scenario to a product's average retail price for the base period of 1982-84. The effect on price at retail, following a scenario action, occurs because the action affects the total (nationwide) quantity of product produced and thus supplied to the retail market. A smaller quantity produced and supplied leads to a higher retail price, and conversely.

For citrus at the consumer level, an average price per pound for fresh oranges, fresh grapefruit, and the fruit equivalent contained in frozen concentrated orange juice is used. This average price for citrus fruit at the consumer level is a weighted average; the weights and averaging method are explained in Table 56, which also explains base period price averaging methods for the other consumer products studied. Even though the impact on citrus production of any of the scenarios was estimated to be very small--1 percent at the most--citrus has been included at the consumer level nevertheless. Tobacco (cigarettes at retail) has also been included, because several scenarios show a change in production of 2 percent, even though other scenario impacts on quantity produced are zero. However, cotton products have been excluded from the consumer impact analysis because scenario percentage impact on cotton production is just about zero.

As a simplifying assumption, potatoes are all assumed to reach consumers as fresh product; prices of processed potato products are not considered in the base period average. Fresh and processed tomatoes were considered as two commodities even for the producer analysis. The processing tomato crop is destined for some kind of processing plant; in this study, retail prices of canned tomatoes are used to represent the prices of all processed tomato products and are stated on the basis of the price per pound of the raw tomato equivalent contained in canned tomatoes.

It is assumed that the percentage change in the quantity of a product offered for sale at retail is the same as the percentage change in the quantity of that product produced by all farms (nationwide) as the result of the action of one of the scenarios. The percentage change, by crop, in the quantity

produced by all farms is calculated from the estimates shown in Table 57, and is then placed into the price flexibility formula presented in Appendix B, along with the base period average retail price, calculated as explained above and in Table 56. The elasticity values entered into the formula are for retail direct price elasticities of demand for the products in question. (Appendix B.) These values are estimated as also explained in Appendix B; in the case of citrus, the values are a weighted average of the individual retail elasticities for fresh oranges, fresh grapefruit, and fruit juices, weighted according to the relative amounts of each moving to market (juice quantity stated in fresh fruit equivalent). Given the change in quantity for each scenario, the formula then gives an estimate for the "new" average price for the product under each of the seven scenarios.

Finally, the magnitude of retail price increase or decrease is expressed as a percentage change from the base period average price, by product. The estimates of the consumer price impacts retain their short-run character, just as with the estimates of producer price impacts.

Economic Impacts on Crop Producers

According to the biological estimates, the yield of a crop in the field typically decreases in response to the alternative practices and chemicals used because of a scenario action. (See biological estimates in Tables 1-39.) (However, there are some important exceptions in which crop yield does not change at all, or even increases.) Given the short-run assumption that acreage planted to each of the crops does not change after a scenario action, a change in yield leads to a change in total production of a crop.

A decrease in production of a crop would usually lead to a rise in the crop price received by the farmer, and to an increase in gross revenue received by the farmer for the crop sold, assuming that the influence of farm and commercial stocks on the price were neutral. In the case of yield decrease, the farmer's gross revenue would increase, since the effect of higher prices on the farmer's revenue is greater than the effect of lower production, given the price elasticities of demand for those specific crops.

However, in many cases, the costs of soil-borne pest control using alternative practices and chemicals are higher than the costs of using those soil fumigants banned by the scenario actions. Therefore, a gross revenue increase would typically be offset to some extent by higher pest control costs. For any crop, the net revenue change attributable to a scenario action is the gross revenue change minus the control cost change.

While the impacts are aggregated or averaged over all producers of a given crop, only a small acreage may actually be treated with the scenario fumigants. As a result, the effect of losing one or more fumigants could have no effect on growers not using fumigants, but a devastating effect on growers using them. The severity of adverse impacts is diluted when averaged over all planted acreage, treated and not treated.

Table 55 shows how each of the scenarios would change producers' net revenues by crop in East and West regions (North and South for tree seedlings). These net revenue changes can be put into better perspective if they are related to the total value of the crop in question. (See table below on change in net revenue to producers.) For example, even if total dollar effects of a fumigant regulatory action were larger for a high value crop than for a lesser

value crop, the smaller total dollar effects would be more "significant" if they were a higher percentage of the value of the affected crop. As it turns out, those crops of highest total value, namely cotton and tobacco, are not the crops most affected by the seven scenarios of possible fumigant regulation; cotton and tobacco are hardly affected at all.

Thus, total crop value can be viewed as a standard against which the magnitude or intensity of net revenue changes can be judged, by crop. Also, possible differences in regional impacts between East and West (North and South for tree seedlings) can be highlighted in this fashion. In the base year (1982-84 average), the total value at the farm level of each of the crops studied (for regions as defined above, including the main producing States but not necessarily all 50 States) are shown as follows:

1982-84 annual average value of crops studied for fumigant assessment

Crop	Total farm value a/		
	Both regions	East	West
	(Billion dollars)		
Cotton	3.3	1.2	2.1
Tobacco	3.0	3.0	0
Potatoes	1.8	0.4	1.5
Citrus	1.6	1.0	0.6
Tomatoes--fresh	0.6	0.5	0.2
Tomatoes--processing	0.5	0.1	0.4
	(Million dollars)		
Citrus seedlings	390	225	165
Forest seedlings	206	North: 131	South: 75
Tobacco seedlings	[Not marketed]		0
Tomato seedlings	22	22	0

a/ From Table 54.

In the next table, the changes in net revenue to producers, by crop and scenario, are stated as percentages of the above regional values of the crops. These percentages are then used to analyze impacts of each of the scenarios.

Change in net revenue to producers as a percentage of crop value, by scenario a/

Crop	Scenario 1	2	3	4	5	6	7
	Percent						
Citrus							
East	0	1	0	0	1	1	1
West	0	0	0	0	*	*	*
Cotton							
East	0	0	0	0	0	-*	*
West	*	0	0	0	*	*	*
Potatoes							
East	3	0	0	-1	8	8	3
West	14	0	0	-18	20	20	16
Tobacco							
East	-*	0	0	0	-*	-*	1
Tomatoes, fresh							
East	-16	9	0	-6	4	4	11
West	1	4	0	-2	3	3	2
Tomatoes, processing							
East	0	0	0	0	0	0	0
West	7	0	0	-*	7	7	7
Citrus seedlings							
East	0	-1	0	0	*	*	-1
West	0	-5	0	0	-5	-5	-5
Tobacco seedlings							
East	[Tobacco seedlings grown by producers for own use.]						
Tomato seedlings							
East	1	-6	0	0	-11	-11	-6
Forest seedlings							
North	0	4	3	0	6	6	4
South	0	4	7	0	-39	-39	4

a/ Percentages calculated from data on Tables 54 and 55.
* Value less than 1/2 of 1 percent.
\- Minus sign indicates that net revenue decreased from base period value, either because farm value of product decreased or because costs of soil-borne pest control increased, or because of a combination of both.

Scenario 1--1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control: The economic impact of this scenario action falls most heavily on producers of fresh tomatoes in the East, who experience a decrease in net revenues of about 16 percent of crop value. The revenue decrease occurs mainly because much fresh tomato crop acreage is treated in the East, but not in the West, and because the substitution of methyl bromide for 1,3-D raises crop yield, and is considerably more costly (Table 30). The other strong economic impact of this scenario is on producers of potatoes in the West, whose net revenues increase by 14 percent of crop value. This impact in the West occurs because it costs less per acre to treat with metam by irrigation than with 1,3-D + MIC by injection, the alternative chemical, while there is no change in yield. (Tables 19 and 20). Net revenues increase by 3 percent of crop value for potato growers in the East, whose treated acreage and treatment practices differ from those in the West.

For growers of processing tomatoes in the West, net revenues increase by 7 percent of crop value. Producers of tobacco seedlings in the East would experience a sharp decrease in seedling yield of almost 61 percent, and a major increase in control costs of an estimated $250 per acre as seedlings are grown out on tobacco seedbeds, because methyl bromide and soilless mix would very likely be substituted for 1,3-D. (Tables 23 and 27.) Producers of eastern tomato seedlings would experience a minor increase in net revenue of 1 percent of crop value. Growers of other crops in either region would experience no or almost no economic impact from Scenario 1.

Scenario 2--Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in Scenario 1: The impact of this scenario action is confined almost entirely to producers of fresh tomatoes in the East, whose net revenues increase by an amount equal to 9 percent of base period crop value. Fresh tomato yields would decrease as fumigant 1,3-D is substituted for methyl bromide, leading to higher tomato prices, and lower pest control costs. Net revenues of fresh tomato producers in the West increase much less, by only 4 percent of crop value. However, this difference between aggregate results for East and West tomato growers is principally because much less fresh tomato acreage is treated for soil-borne pests in the West than in the East. For citrus growers in the East, this scenario shows only a 1 percent increase. For growers of citrus seedlings in the West, net revenues would decrease by 5 percent of crop value; for producers of forest tree seedlings in the North and South, revenues would increase somewhat--by 4 percent for each. In the East, grower revenue from tomato seedlings would drop by 6 percent of crop value.

Scenario 3--Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in Scenario 1: The impacts, by crop, of this scenario action are either negligible or zero, except for forest seedlings, where net revenues increase by an estimated 3 percent and 7 percent of crop value in North and South, respectively.

Scenario 4--Metam is lost. All other fumigants plus alternatives are available, as in Scenario 1: This scenario adversely affects growers of potatoes and fresh tomatoes, but does not affect growers of other crops. Potato growers in the West would experience a decline in net revenues

equivalent to 18 percent of the value of the western potato crop, but growers in the East would have to take a decrease in net revenue of only 1 percent of eastern potato crop value. In the West, the substitution of 1,3-D for metam would lead to an increase in soil-borne disease control costs, but with an increase in yield as well. Consequently, prices received by farmers for potatoes would decline, especially in the face of a highly price-inelastic demand for potatoes. (Table 53.) An estimated 24 percent of the potato acreage is treated in the West, but only 5 percent is treated in the East. Growers of fresh tomatoes in the East would experience a decrease in net revenues of about 6 percent of eastern fresh tomato crop value. With MC-33 as the alternative to metam for tomato disease control in both the East and West, yield would increase in both regions, lowering prices received, at the same time that control costs with MC-33 would be greater than with metam. (Table 34.) In the West, the decrease in net revenues is 2 percent, compared to the 6 percent in the East, only because the proportion of acreage treated is less in the West. Impacts on other crops are negligible or zero.

Scenario 5--All fumigants are lost, but non-fumigant alternatives are available: The greatest impact is again felt by potato producers in the West, who receive an increase in net revenues estimated at 20 percent of crop value. Yield per acre declines 20 percent, raising receipts from the western potato crop because of inelastic demand and higher prices, while control costs also decrease as non-fumigant chemicals or no control practices are used. The aggregate increase in net revenue to eastern potato growers is only 8 percent, mainly because treated acreage of potatoes is much less in the East than in the West and because treatment cost decreases. Growers of processing tomatoes in the West would receive a 7 percent increase in net revenues (percent of

total crop value), because the lack of any practical alternative chemical controls for nematodes decreases control costs on the one-third of acreage which was treated with fumigants. Also, yields of processing tomatoes would decline about 11 percent, leading to higher product prices received by farmers for this commodity. (Tables 50 and 53.) Producers of fresh tomatoes in the East and West would find their net returns increasing by about the same amount, 4 percent and 3 percent, respectively, of total crop value in the base period. However, yields of fresh tomatoes would decline about 64 percent in the East, as no practical chemical controls could replace the fumigants used against nematodes and diseases. As a result, control costs decline substantially (Tables 30 and 34), while fresh tomato prices would rise from $25 to $45 per cwt. On balance for the growers, the precipitous drop in production quantity is barely offset by the combined effects of higher prices and lower control costs. In the West, fresh tomato yields would decline 25 percent, and control costs would drop less than in the East.

Producers of forest seedlings in the South would feel a severe drop in net revenues of 39 percent of crop value, as the loss of all fumigants would require them to spend $350 more per acre for control of weeds and diseases, while seedling yield per acre would plummet by 75 percent. Here is a case in which a price increase because of lower production, which frequently boosts revenues, is overwhelmed by the combined effects of higher production costs and much lower quantity produced. Growers of forest seedlings in the North would also be adversely affected, but because it takes 2 or 3 years to produce a seedling in the North (only 1 year in the South), the full impact on northern growers would not show up the first year after fumigant loss. Because the seedling production cycle is longer in the North than in the

South, _in any one year_ only about 23 percent of northern tree seedbed acreage is fumigated, although almost all tree seedbed acreage is fumigated in both regions prior to planting each seedling crop. As a result, the first year after fumigants were lost northern growers in the aggregate would receive net revenues 6 percent higher than crop value in the base period. The higher revenues would come from sale of harvested seedlings whose seedbeds were treated with fumigants a year or two earlier, but in subsequent years net revenues would drop as higher control costs and lower yields took their toll.

In the East, this scenario causes a net revenue decline for tomato seedling growers of 11 percent of crop value. In the West, net revenues of producers of citrus seedlings decrease by an amount equal to 5 percent of crop value. Other changes attributable to this scenario are 1 percent of crop value or less.

Scenario 6--All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available: Except for a negligible impact on cotton in the East, the impact of Scenario 6 on producers is exactly the same as the impact of Scenario 5.

Scenario 7--Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control: Again, this scenario action affects potato and tomato growers, but producers of the other crops in the study hardly at all. In the West, potato growers' net revenues increase by 16 percent of crop value. Potato yields per acre decline by 15 percent as metam and ethoprop are substituted for 1,3-D (and mixture); control costs increase, but not by enough to nullify the increase in crop value because of lower production and higher prices. In the

East, net revenues from fresh tomatoes rise an amount which is about 11 percent of crop value, because per acre yields decline by 25 percent, also leading to lower production and a price rise. In addition, control costs decline. Other impacts of this scenario are increases equivalent to 7 percent of crop value for processing tomatoes in the West, 4 percent for forest seedlings, 3 percent for potatoes in the East, and 2 percent for fresh tomatoes in the West. There are also revenue declines--6 percent for tomato seedlings in the East, and 5 percent for citrus seedlings in the West. Other impacts are at the 1-percent level or negligible.

Comparisons of scenario aggregates: A crude comparative measure of the scenario impact is the aggregate dollar value of the changes in net revenue for all the crops studied. (Table 55) By this measure, for field crops only, Scenarios 5 and 6 (involving the loss of all fumigants) cause the greatest aggregate dollar increase in net revenues, while Scenario 4 has the only revenue-decreasing effect. By contrast, Scenario 3 has no influence at all.

Considering only seedling crops, Scenario 3 has a revenue-increasing impact on seedling producers, while Scenarios 5 and 6 have the greatest aggregate revenue-decreasing impact, primarily through effects on forest nurseries in the South.

However, these aggregates must be interpreted with caution, because they do not include all crops on which the fumigants and their substitutes are used. Also, these aggregates include cotton and citrus, whose growing areas receive very little fumigation for soil-borne pests, although, for citrus, fumigation prior to seedling growth or transplant is more widespread. Moreover, crop acreages of even tomatoes and potatoes, which the study shows to be the crops

most affected by the scenario actions, are not fully treated with soil fumigants. When there are significant portions of a crop's acreage untreated, an aggregate appraisal of a net revenue effect averaged over all growers does not explain important differences in impact among growers of the same crop.

Another caution is also warranted in interpreting the net revenue figures. They are the results of only partial budgeting analysis in which all costs of production (which offset gross revenues) are not considered--only costs of controlling soil-borne pests. It is possible that when soil-borne pest control costs change, other, linked production costs could change as well.

As a general rule across all scenarios, in computing net revenue effects by the above partial budgeting concept, the change in gross revenues from sale of crop tends to far outweigh the change in production cost associated with the same scenario.

There may be a transfer of income from growers most affected by fumigant cancellation to those growers least affected. All growers receive the higher price resulting from a reduction in yield, but the higher price may not offset the lower yields and higher costs of those producers most affected.

Crop impacts, by scenario: Growers of potatoes in the West are the growers most affected, positively or negatively, by scenario actions. For Scenarios 1, 5, 6, and 7, the impact is positive; in each case net returns increase by a dollar value which is 14 percent or more of potato crop value in the West. For Scenario 4, the impact is negative, as potato returns drop by an amount equal to 18 percent of potato value in the base period. There is no impact from Scenario 2 or 3. Growers of fresh tomatoes in the East are also affected, but somewhat less than western potato producers. For eastern fresh tomatoes,

impacts over 10 percent of crop value occur from Scenarios 1 and 7, with the more severe of these from Scenario 1, causing a net revenue decrease equivalent to 16 percent of crop value. Scenario 4 also leads to a net revenue decline for eastern tomato growers, a decline of 6 percent of crop value. Other large impacts from Scenarios 5 and 6 are on producers of forest tree seedlings in the South (minus 39 percent), eastern tomato seedling growers (minus 11 percent), eastern potato growers and on growers of processing tomatoes in the West. For other crops, impacts are at the 5-percent level or less, most of which are at a level between 1 percent (+ or -) and zero.

Therefore, scenario economic impacts on producers of the field crops included in the study would be largely limited to growers of potatoes and tomatoes. Some scenario actions affecting producers of these crops add to growers' net revenues, although some of these actions impinge on and decrease these revenues. No impact, plus or minus, on farmers' net revenue from a field crop is greater than an amount equivalent to 20 percent of the value of the crop in the base period of the study. Most impacts are much less.

In general, producers of marketed seedlings of tomato, forest trees, and citrus trees are affected significantly, as net revenue changes equivalent to 5 percent or more of seedling crop value are common. The major change is the large decrease in net revenue to growers of forest tree seedlings in the South equivalent to 39 percent of crop value. The main impacts on growers of marketed seedlings occur under Scenarios 5, 6, and 7.

Impacts on Consumers

Impacts on consumers are expressed as percentage changes in retail prices of consumer-level commodities/products prepared from the crops included in this study. The method by which retail price changes have been estimated has been explained above, in the section on estimating the impacts on consumers. The retail price changes are shown as percentage changes from base period prices in the following table. An analysis of these changes follows, scenario-by-scenario:

Scenario 1--1,3-D singly and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control: Supplies of potatoes, processing tomatoes, and tobacco decrease under this scenario; therefore, given price elasticities of demand for the respective retail products, the retail price of potatoes would increase by 8 percent, of canned tomatoes by 7 percent, and of cigarettes by 4 percent. The retail price of fresh tomatoes would decrease by 15 percent because of the sharp increase in production of this crop. There is no impact on the average retail price of citrus fruit.

Scenario 2--Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in Scenario 1. There is no impact of this scenario on retail prices, except upon the retail price of fresh tomatoes. The price of these is projected to rise 22 percent because the scenario action leads to a substantial decline in fresh tomato production.

Scenario 3--Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in Scenario 1: There is no

Retail price increase or decrease from base period a/

Product	Scenario						
	1	2	3	4	5	6	7
	Percent						
Citrus fruit b/	0	0	0	0	0	0	0
Potatoes	+ 8	0	0	- 8	+ 11	+ 11	+ 8
Tobacco c/	+ 4	0	0	0	+ 4	+ 4	+ 4
Tomatoes, fresh	- 15	+ 22	0	- 6	+ 53	+ 53	+ 20
Tomatoes, canned	+ 7	0	0	+ 1	+ 8	+ 8	+ 7

a/ Calculated from Table 58.

b/ Fresh fruit (oranges and grapefruit) and fresh fruit equivalent in frozen concentrated orange juice

c/ Cigarettes

impact of this scenario on retail prices of the products studied because there is no impact of the scenario on production of the respective crops.

Scenario 4--Metam is lost. All other fumigants plus alternatives are available, as in Scenario 1: Because of the larger production of both potatoes and fresh tomatoes under this scenario, the average potato price declines 8 percent at retail and the average fresh tomato price falls 6 percent. The retail price of canned tomatoes increases 1 percent.

Scenario 5--All fumigants are lost, but non-fumigant alternatives are available: The loss of all fumigants has a price-increasing impact at retail on all the consumer commodities considered. The largest influence is on the average price of fresh tomatoes, which increases by 53 percent because of a steep decline in the quantity produced. The average retail price of potatoes would increase by 11 percent, of canned tomatoes by 8 percent, and of cigarettes by 4 percent.

Scenario 6--All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available: The impact of Scenario 6 on consumers through retail prices is the same as for Scenario 5.

Scenario 7--Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control: The retail price increase for fresh tomatoes is of lesser magnitude than under Scenarios 5 and 6, but still amounts to a large increase, of 20 percent. The increase in the potato price is 8 percent, the canned tomato price increase 7 percent, and the cigarette price increase 4 percent.

Consumer commodity impact: Considering the commodity impact across all scenarios, it is clear that the main burden of price increase would fall on consumers of fresh tomatoes, followed by a somewhat lesser burden of higher prices on potato consumers. By implication, products which can readily substitute for tomatoes and potatoes should experience an increase in quantity demanded. Alternatively, if supplies of tomatoes or potatoes were available in exporting countries, some might be shipped to the U.S. in response to a rise in U.S. prices. Thus, imports could tend to counteract a decrease in domestic quantity supplied as a result of fumigant regulation. If an import flow were triggered, this flow would, of course, tend to moderate the price rise projected in this report. In this case, it would be important to know whether foreign producers were employing those fumigants banned in the U.S., in effect exploiting U.S. pesticide regulation to their advantage.

Table 47. Proportion of planted acres treated by pest controlled, by crop, base year

Crop	Acres planted	Acres treated annually	Acres treated to control: All pests	Nematodes	Weeds	Diseases	Insects
East	1,000	1,000	— Percent of planted acres —				
Citrus							
Seedbed	3.0	1.1	35.00	14.00	0.00	35.00	0.00
Field	668.0	0.5	0.07	0.07	0.00	0.07	0.00
Cotton							
Field	2,893.0	5.8	0.20	0.20	0.00	0.00	0.00
Potatoes							
Field	273.0	13.7	5.00	4.00	0.00	5.00	0.00
Tobacco							
Seedbed	14.0	14.0	100.00	100.00	100.00	100.00	0.00
Field	833.0	416.5	50.00	50.00	0.00	7.00	0.00
Tomatoes, fresh							
Seedbed	6.5	3.0	46.00	46.00	0.00	39.00	0.00
Field	94.0	59.2	63.00	61.00	58.00	63.00	0.00
Tomatoes, processing							
Field	59.0	0.0	0.00	0.00	0.00	0.00	0.00
West							
Citrus							
Seedbed	2.2	0.3	12.70	12.70	0.00	12.00	0.00
Field	358.0	3.6	1.00	1.00	0.00	0.00	0.00
Cotton							
Field	7,174.0	36.0	0.05	0.05	0.00	0.00	0.00
Potatoes							
Field	1,031.0	237.1	23.00	23.00	3.00	7.00	0.00
Tobacco							
Seedbed	-	0.0	-	-	-	-	-
Field	-	0.0	-	-	-	-	-
Tomatoes, fresh							
Seedbed	-	0.0	-	-	-	-	-
Field	33.8	3.0	9.00	8.00	0.00	9.00	0.00
Tomatoes, processing							
Field	248.0	81.8	33.00	33.00	5.00	0.00	0.00
North							
Forest nurseries							
Seedbed	3.5	0.8	23.43	0.00	23.43	23.43	0.00
South							
Forest nurseries							
Seedbed	2.0	2.0	95.82	0.00	95.82	95.82	0.00
All regions							
Seedbed	31.2	21.1	64.60	56.63	53.69	66.01	0.00
Field	13,664.8	857.2	8.80	6.00	0.72	1.50	0.00

- = crop not grown.

Table 48. Projected change in control cost per acre by scenario, by crop a/

Crop	Change in control cost per acre, by scenario:						
	1	2	3	4	5	6	7
East	— Dollars per acre —						
Citrus							
Seedbed	NA	200	NA	NA	500	500	80
Field	NA	-386	NA	NA	-425	-425	-386
Cotton							
Field	0	NA	NA	NA	0	13	-13
Potatoes							
Field	50	NA	NA	377	-44	-44	50
Tobacco							
Seedbed	250	200	NA	NA	200	200	200
Field	97	NA	NA	NA	98	98	50
Tomatoes, fresh							
Seedbed	300	-300	NA	NA	-83	-83	-329
Field	150	50	NA	100	160	160	-50
Tomatoes, processing							
Field	NA	NA	NA	NA	NA	NA	NA
West							
Citrus							
Seedbed	NA	467	NA	NA	21	21	-412
Field	0	NA	NA	0	0	0	0
Cotton							
Field	-13	NA	NA	NA	-13	-13	-13
Potatoes							
Field	61	NA	NA	138	-15	-15	-60
Tobacco							
Seedbed	-	-	-	-	-	-	-
Field	-	-	-	-	-	-	-
Tomatoes, fresh							
Seedbed	-	-	-	-	-	-	-
Field	0	-600	NA	600	-418	-418	-600
Tomatoes, processing							
Field	-100	NA	NA	55	-84	-84	-100
North							
Forest nurseries							
Seedbed	NA	-100	-150	NA	350	350	-100
South							
Forest nurseries							
Seedbed	NA	-150	-175	NA	450	450	-150

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) are not registered for indicated use.
- = crop not grown.

a) The seven scenarios are defined as follows: 1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. 2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 3) Chloropicrin singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item 1). 4) Metam is lost. All other fumigants plus alternatives are available, as in item 1). 5) All fumigants are lost, but non-fumigant alternatives are available. 6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. 7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

Table 49. Projected change in total control cost by scenario, by crop a/

Crop	Change in total control cost, by scenario: 1	2	3	4	5	6	7
	— $1,000 —						
East							
Citrus							
Seedbed	0	210	0	0	525	525	84
Field	0	(180)	0	0	(199)	(199)	(180)
Cotton							
Field	0	0	0	0	0	75	(75)
Potatoes							
Field	683	0	0	5,146	(601)	(601)	683
Tobacco							
Seedbed	3,500	2,800	0	0	2,800	2,800	2,800
Field	40,401	0	0	0	40,817	40,817	20,825
Tomatoes,fresh							
Seedbed	897	(897)	0	0	(248)	(248)	(984)
Field	8,883	2,961	0	5,922	9,475	9,475	(2,961)
Tomatoes,processing							
Field	0	0	0	0	0	0	0
Region							
West							
Citrus							
Seedbed	0	130	0	0	6	6	(115)
Field	0	0	0	0	0	0	0
Cotton							
Field	(468)	0	0	0	(468)	(468)	(468)
Potatoes							
Field	14,465	0	0	32,724	(3,557)	(3,557)	(14,228)
Tobacco							
Seedbed	–	–	–	–	–	–	–
Field	–	–	–	–	–	–	–
Tomatoes,fresh							
Seedbed	–	–	–	–	–	–	–
Field	0	(1,825)	0	1,825	(1,272)	(1,272)	(1,825)
Tomatoes,processing							
Field	(8,184)	0	0	4,501	(6,875)	(6,875)	(8,184)
North							
Forest nurseries							
Seedbed	0	(82)	(123)	0	287	287	(82)
South							
Forest nurseries							
Seedbed	0	(293)	(341)	0	878	878	(293)
All regions							
Seedbed	4,397	1,869	(464)	0	4,247	4,247	1,411
Field	55,779	955	0	50,118	37,322	37,397	(6,414)

– = crop not grown.

a/ Scenarios defined in Table 48, footnote a/.

Table 50. Projected change in yield per acre by scenario, by crop a/

Crop	Yield, base year	Unit	Change in base year yield, by scenario: 1	2	3	4	5	6	7
			— Percent —						
East									
Citrus		1,000							
Seedbed	500.0	Seedlings	NA	-2.6	NA	NA	1.4	1.4	-4.6
Field	11.3	Tons	NA	-25.0	NA	NA	-25.0	-25.0	-25.0
Cotton									
Field	1.4	Bales	0.0	NA	NA	NA	0.0	-3.0	-3.0
Potatoes									
Field	210.9	Cwt.	-11.9	NA	NA	0.0	-33.9	-33.9	-11.9
Tobacco		1,000							
Seedbed	1,186.0	Seedlings	60.7	-30.7	NA	NA	-30.7	-30.7	-30.7
Field	2,067.6	Pounds	-4.0	NA	NA	NA	-4.0	-4.0	-4.0
Tomatoes, fresh		1,000							
Seedbed	304.0	Seedlings	10.0	-30.2	NA	NA	-40.4	-40.4	-30.2
Field	201.6	Cwt.	19.5	-25.1	NA	7.0	-64.2	-64.2	-25.1
Tomatoes, processing									
Field	19.4	Tons	NA	NA	NA	NA	NA	NA	NA
West									
Citrus		1,000							
Seedbed	500.0	Seedlings	NA	-78.6	NA	NA	-78.6	-78.6	-81.0
Field	11.0	Tons	0.0	NA	NA	0.0	-30.0	-30.0	-30.0
Cotton									
Field	1.0	Bales	-3.0	NA	NA	NA	-3.0	-3.0	-3.0
Potatoes									
Field	283.9	Cwt.	-15.0	NA	NA	14.7	-20.1	-20.1	-15.0
Tobacco									
Seedbed	-	Seedlings	-	-	-	-	-	-	-
Field	-	Pounds	-	-	-	-	-	-	-
Tomatoes, fresh		1,000							
Seedbed	-	Seedlings	-	-	-	-	-	-	-
Field	225.8	Cwt.	-17.2	-30.3	NA	6.0	-25.5	-25.5	-6.0
Tomatoes, processing									
Field	25.3	Tons	-10.0	NA	NA	-1.5	-11.3	-11.3	-10.0
North									
Forest nurseries		1,000							
Seedbed	750.0	Seedlings	NA	-36.0	-20.0	NA	-75.0	-75.0	-36.0
South									
Forest nurseries		1,000							
Seedbed	750.0	Seedlings	NA	-36.0	-20.0	NA	-75.0	-75.0	-36.0

NA = not applicable. Reflects no use of suspended pesticide(s) in base year; or alternative pesticide(s) are not registered for indicated use.

- = crop not grown.

a/ Scenarios defined in Table 48, footnote a/.

Table 51. Projected change in yield per acre on treated acres, by scenario, by crop a/

Crop	Yield, base year	Unit	Yield per acre, by scenario: 1	2	3	4	5	6	7
East									
Citrus		1,000							
Seedbed	500.0	Seedlings	500.0	487.0	500.0	500.0	507.0	507.0	477.0
Field	11.3	Tons	11.3	8.5	11.3	11.3	8.5	8.5	8.5
Cotton									
Field	1.4	Bales	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Potatoes									
Field	210.9	Cwt.	185.8	210.9	210.9	210.9	139.4	139.4	185.8
Tobacco		1,000							
Seedbed	1,186.0	Seedlings	1,905.9	821.9	1,186.0	1,186.0	821.9	821.9	821.9
Field	2,067.6	Pounds	1,984.9	2,067.6	2,067.6	2,067.6	1,984.9	1,984.9	1,984.9
Tomatoes,fresh		1,000							
Seedbed	304.0	Seedlings	334.4	212.2	304.0	304.0	181.2	181.2	212.2
Field	201.6	Cwt.	240.9	151.0	201.6	215.7	72.2	72.2	151.0
Tomatoes,processing									
Field	19.4	Tons	19.4	19.4	19.4	19.4	19.4	19.4	19.4
West									
Citrus		1,000							
Seedbed	500.0	Seedlings	500.0	107.0	500.0	500.0	107.0	107.0	95.0
Field	11.0	Tons	11.0	11.0	11.0	11.0	7.7	7.7	7.7
Cotton									
Field	1.0	Bales	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Potatoes									
Field	283.9	Cwt.	241.3	283.9	283.9	325.6	226.8	226.8	241.3
Tobacco									
Seedbed	-	Seedlings	-	-	-	-	-	-	-
Field	-	Pounds	-	-	-	-	-	-	-
Tomatoes,fresh		1,000							
Seedbed	-	Seedlings	-	-	-	-	-	-	-
Field	225.8	Cwt.	187.0	157.4	225.8	239.3	168.2	168.2	212.3
Tomatoes,processing									
Field	25.3	Tons	22.8	25.3	25.3	24.9	22.4	22.4	22.8
North									
Forest nurseries		1,000							
Seedbed	750.0	Seedlings	750.0	480.0	600.0	750.0	187.5	187.5	480.0
South									
Forest nurseries		1,000							
Seedbed	750.0	Seedlings	750.0	480.0	600.0	750.0	187.5	187.5	480.0

- = crop not grown.

a/ Scenarios defined in Table 48, footnote a/.

Table 52. Projected total production by scenario, by crop a/

Crop	Production base year	Unit	Production, by scenario: 1	2	3	4	5	6	7
	1,000					1,000			
East									
Citrus		1,000							
Seedbed	1,500	Seedlings	1,500	1,486	1,500	1,500	1,507	1,507	1,476
Field	7,548	Tons	7,548	7,547	7,548	7,548	7,547	7,547	7,547
Cotton									
Field	4,050	Bales	4,050	4,050	4,050	4,050	4,050	4,050	4,050
Potatoes									
Field	57,576	Cwt.	57,233	57,576	57,576	57,576	56,600	56,600	57,233
Tobacco		1,000							
Seedbed	16,604	Seedlings	26,683	11,507	16,604	16,604	11,507	11,507	11,507
Field	1,722,311	Pounds	1,687,865	1,722,311	1,722,311	1,722,311	1,687,865	1,687,865	1,687,865
Tomatoes,fresh		1,000							
Seedbed	1,976	Seedlings	2,067	1,701	1,976	1,976	1,609	1,609	1,701
Field	18,950	Cwt.	21,278	15,954	18,950	19,786	11,286	11,286	15,954
Tomatoes,processing									
Field	1,145	Tons	1,145	1,145	1,145	1,145	1,145	1,145	1,145
West									
Citrus		1,000							
Seedbed	1,100	Seedlings	1,100	990	1,100	1,100	990	990	987
Field	3,938	Tons	3,938	3,938	3,938	3,938	3,926	3,926	3,926
Cotton									
Field	7,174	Bales	7,173	7,174	7,174	7,174	7,173	7,173	7,173
Potatoes									
Field	292,701	Cwt.	282,603	292,701	292,701	302,597	279,169	279,169	282,603
Tobacco									
Seedbed	-	Seedlings	-	-	-	-	-	-	-
Field	-	Pounds	-	-	-	-	-	-	-
Tomatoes,fresh		1,000							
Seedbed	-	Seedlings	-	-	-	-	-	-	-
Field	7,632	Cwt.	7,514	7,424	7,632	7,673	7,457	7,457	7,591
Tomatoes,processing									
Field	6,274	Tons	6,067	6,274	6,274	6,243	6,040	6,040	6,067
North									
Forest nurseries		1,000							
Seedbed	2,625	Seedlings	2,625	2,404	2,502	2,625	2,164	2,164	2,404
South									
Forest nurseries		1,000							
Seedbed	1,526	Seedlings	1,526	1,000	1,234	1,526	429	429	1,000

- = crop not grown.

a/ Scenarios defined in Table 48, footnote a/.

Table 53. Projected farm or nursery price per unit by scenario, by crop a/

Crop	Price per unit, base year	Unit	Price elasticity	Price per unit, by scenario: 1	2	3	4	5	6	7
				— Dollars per unit —						
East										
Citrus										
Seedbed	437.50	1,000 Seedling	-0.60	437.50	444.14	437.50	437.50	433.93	433.93	449.24
Field	133.73	Ton	-0.55	133.73	133.77	133.73	133.73	133.77	133.77	133.77
Cotton										
Field	288.03	Bale	-0.60	288.03	288.03	288.03	288.03	288.03	288.06	288.06
Potatoes										
Field	6.17	Cwt.	-0.18	6.38	6.17	6.17	6.17	6.75	6.75	6.38
Tobacco										
Seedbed	b/	1,000 Seedlings	b/	b/	b/	b/	b/	b/	b/	b/
Field	1.77	Pounds	-0.60	1.83	1.77	1.77	1.77	1.83	1.83	1.83
Tomatoes, fresh										
Seedbed	11.00	1,000 Seedlings	-0.50	9.99	14.06	11.00	11.00	15.09	15.09	14.06
Field	24.97	Cwt.	-0.52	19.02	32.63	24.97	22.83	44.56	44.56	32.63
Tomatoes, processing										
Field	85.23	Tons	-0.38	85.23	85.23	85.23	85.23	85.23	85.23	85.23
West										
Citrus										
Seedbed	437.50	1,000 Seedlings	-0.60	437.50	510.29	437.50	437.50	510.29	510.29	512.51
Field	141.60	Tons	-0.55	141.60	141.60	141.60	141.60	142.38	142.38	142.38
Cotton										
Field	297.17	Bales	-0.60	297.24	297.17	297.17	297.17	297.24	297.24	297.24
Potatoes										
Field	5.09	Cwt.	-0.18	6.07	5.09	5.09	4.13	6.40	6.40	6.07
Tobacco										
Seedbed	-	Seedlings	-0.50	-	-	-	-	-	-	-
Field	-	Pounds	-0.60	-	-	-	-	-	-	-
Tomatoes, fresh										
Seedbed	-	1,000 Seedlings	-0.50	-	-	-	-	-	-	-
Field	21.52	Cwt.	-0.52	22.17	22.66	21.52	21.29	22.48	22.48	21.75
Tomatoes, processing										
Field	66.33	Tons	-0.38	72.07	66.33	66.33	67.19	72.82	72.82	72.07
North										
Forest nurseries										
Seedbed	50.00	1,000 Seedlings	-0.60	50.00	57.03	53.90	50.00	64.64	64.64	57.03
South										
Forest nurseries										
Seedbed	50.00	1,000 Seedlings	-0.60	50.00	78.75	65.97	50.00	109.89	109.89	78.75

- = crop not grown.

a/ Scenarios defined in Table 48, footnote a/.

b/ Tobacco seedlings grown by producers for own use.

Table 54. Projected value of production by scenario, by crop a/

Crop	Value, base year	Value of production, by scenario: 1	2	3	4	5	6	7
		— $1,000 —						
East								
Citrus								
Seedbed	656,250	656,250	660,141	656,250	656,250	654,080	654,080	663,010
Field	1,009,448	1,009,448	1,009,594	1,009,448	1,009,448	1,009,594	1,009,594	1,009,594
Cotton								
Field	1,166,579	1,166,579	1,166,579	1,166,579	1,166,579	1,166,579	1,166,626	1,166,626
Potatoes								
Field	355,242	364,866	355,242	355,242	355,242	382,289	382,289	364,866
Tobacco								
Seedbed	b/	b/	b/	b/	b/	b/	b/	b/
Field	3,048,490	3,087,104	3,048,490	3,048,490	3,048,490	3,087,104	3,087,104	3,087,104
Tomatoes,fresh								
Seedbed	21,736	20,644	23,917	21,736	21,736	24,274	24,274	23,917
Field	473,191	404,727	520,541	473,191	451,802	502,865	502,865	520,541
Tomatoes,processing								
Field	97,554	97,554	97,554	97,554	97,554	97,554	97,554	97,554
West								
Citrus								
Seedbed	481,250	481,250	505,284	481,250	481,250	505,284	505,284	505,766
Field	557,621	557,621	557,621	557,621	557,621	559,003	559,003	559,003
Cotton								
Field	2,131,898	2,132,111	2,131,898	2,131,898	2,131,898	2,132,111	2,132,111	2,132,111
Potatoes								
Field	1,489,848	1,715,691	1,489,848	1,489,848	1,249,299	1,787,964	1,787,964	1,715,691
Tobacco								
Seedbed	-	-	-	-	-	-	-	
Field	-	-	-	-	-	-	-	
Tomatoes,fresh								
Seedbed	-	-	-	-	-	-	-	
Field	164,242	166,554	168,212	164,242	163,399	167,615	167,615	165,065
Tomatoes,processing								
Field	416,181	437,295	416,181	416,181	419,500	439,866	439,866	437,295
North								
Forest nurseries								
Seedbed	131,250	131,250	137,074	134,870	131,250	139,871	139,871	137,074
South								
Forest nurseries								
Seedbed	76,313	76,313	78,727	81,391	76,313	47,184	47,184	78,727
All regions								
Seedbed	1,366,799	1,365,707	1,405,142	1,375,497	1,366,799	1,370,693	1,370,693	1,408,494
Field	10,910,293	11,139,551	10,961,760	10,910,293	10,650,830	11,332,544	11,332,591	11,255,452

- = crop not grown.

a/ Scenarios defined in Table 48, footnote a/.

b/ Tobacco seedlings grown by producers for own use.

Table 55. Projected annual change in revenue to producers by scenario, by crop a/

Crop	Change in control cost plus change in production value, by scenario:						
	1	2	3	4	5	6	7
				— $1,000 —			
East							
Citrus							
Seedbed	0	(4,101)	0	0	1,645	1,645	(6,844)
Field	0	327	0	0	346	346	327
Cotton							
Field	0	0	0	0	0	(29)	122
Potatoes							
Field	8,942	0	0	(5,146)	27,648	27,648	8,942
Tobacco							
Seedbed	b/	b/	b/	b/	b/	b/	b/
Field	(1,786)	0	0	0	(2,203)	(2,203)	17,789
Tomatoes,fresh							
Seedbed	195	(1,284)	0	0	(2,290)	(2,290)	(1,197)
Field	(77,348)	44,389	0	(27,312)	20,198	20,198	50,311
Tomatoes,processing							
Field	0	0	0	0	0	0	0
West							
Citrus							
Seedbed	0	(24,164)	0	0	(24,040)	(24,040)	(24,401)
Field	0	0	0	0	1,382	1,382	1,382
Cotton							
Field	682	0	0	0	682	682	682
Potatoes							
Field	211,378	0	0	(273,273)	301,673	301,673	240,071
Tobacco							
Seedbed	–	–	–	–	–	–	–
Field	–	–	–	–	–	–	–
Tomatoes,fresh							
Seedbed	–	–	–	–	–	–	–
Field	2,312	5,796	0	(2,668)	4,645	4,645	2,649
Tomatoes,processing							
Field	29,298	0	0	(1,182)	30,559	30,559	29,298
North							
Forest nurseries							
Seedbed	0	5,906	3,743	0	8,334	8,334	5,906
South							
Forest nurseries							
Seedbed	0	2,707	5,420	0	(30,006)	(30,006)	2,707
All regions							
Seedbed	195	(20,936)	9,163	0	(46,357)	(46,357)	(23,829)
Field	173,479	50,512	0	(309,581)	384,930	384,901	351,573

– = crop not grown.

a/ Scenarios defined in Table 48, footnote a/.

b/ Tobacco seedlings grown by producers for own use.

Table 56. Retail prices derived for base year a/

Crop	Retail price/pound			Base year retail price per pound
	1982	1983	1984	
	-- Dollars --			
Oranges, fresh	0.495	0.386	0.537	0.473
Grapefruit, fresh	0.361	0.365	0.398	0.375
Citrus, fresh b/				0.429
Oranges, proc. c/				0.173
Citrus, fresh & proc. markets d/				0.281
Potatoes	0.211	0.206	0.242	0.220
Tomatoes, fresh	0.739	0.791	0.807	0.779
Tomatoes, proc. e/	0.549	0.527	0.525	0.343
Tobacco f/				25.580

a/ Cotton prices not derived as there would be minimal price impacts of a fumigant suspension due to the very minor changes in yield.
b/ Prices are weighted averages of both fresh and processing markets.
c/ Price of processed citrus based on price of 16 ounce can of frozen orange juice; \$1.49 per 8.825 pounds of oranges per can equals \$.173 per pound of oranges.
d/ Weighted price reflects 42 percent of citrus sold in the fresh market, 58 percent in processing market.
e/ Base year price derived by multiplying .644 (pounds of canned tomatoes per pound of fresh tomatoes) times \$.533 (price per pound of canned tomatoes).
f/ Base year price derived: \$.87 divided by 20 cigarettes times 588 (number of cigarettes requiring 1 pound of tobacco).

SOURCES:
1. Prices of fresh citrus, potatoes, and tomatoes obtained from Bureau of Labor Statistics (Ralph Parlett, ERS, U.S. Dept. of Agriculture).
2. Prices of processed citrus obtained from Bureau of Labor Statistics (Ben Huang, ERS, U.S. Dept. of Agriculture).
3. Retail tobacco price reflects price of tobacco used in cigarettes only, which use represents about 95 percent of the total market (Verner Grise, ERS, U.S. Dept. of Agriculture).
4. Proportion of farm production sold in fresh and processing markets obtained from "Agricultural Statistics, 1985," U.S. Dept. of Agriculture).
5. Number of fresh oranges and tomatoes per can of tomatoes obtained from <u>Conversion Factors and Weights and Measures</u>, Statistical Bulletin No. 616, ESCS, U.S. Department of Agriculture, March 1979.

Table 57. Projected total production by scenario, by crop a/

Crop b/	Production, base year	Production, by scenario: 1	2	3	4	5	6	7
	1,000 lbs.							
Citrus	22,972,800	22,972,800	22,970,158	22,972,800	22,972,800	22,946,530	22,946,530	22,946,530
Potatoes	35,027,660	33,983,584	35,027,660	35,027,660	36,017,282	33,576,913	33,576,913	33,983,584
Tobacco	1,722,311	1,687,865	1,722,311	1,722,311	1,722,311	1,687,865	1,687,865	1,687,865
Tomatoes,fresh	2,658,244	2,879,235	2,337,769	2,658,244	2,745,937	1,874,261	1,874,261	2,354,460
Tomatoes,proc.	14,838,000	14,423,890	14,838,000	14,838,000	14,775,883	14,370,055	14,370,055	14,423,890

a/ Scenarios defined in Table 48, footnote a/.
(1) 1,3-D, (2) methyl bromide, (3) chloropicrin, (4) metam, (5) all fumigants,
(6) all fumigants and carbamates (aldicarb, carbofuran, oxamyl), and
(7) 1,3-D, methyl bromide, and carbamates

b/ Change in cotton production not derived as there would be very minor changes in yield using scenario alternatives.

Table 58. Projected retail price per unit by scenario, by crop a/

Crop	Price per pound, base year	Price elasticity	Price per unit, by scenario: 1	2	3	4	5	6	7
			-- Dollars per unit --						
Citrus	0.281	-0.660	0.281	0.281	0.281	0.281	0.281	0.281	0.281
Potatoes	0.220	-0.369	0.238	0.220	0.220	0.203	0.245	0.245	0.238
Tobacco	25.580	-0.500	26.603	25.580	25.580	25.580	26.603	26.603	26.603
Tomatoes, fresh	0.779	-0.558	0.663	0.947	0.779	0.733	1.191	1.191	0.939
Tomatoes, proc.	0.343	-0.381	0.368	0.343	0.343	0.347	0.371	0.371	0.368

a/ Scenarios defined in Table 48, footnote a/.

b/ Change in cotton prices not derived as there would be minimal price impacts of a fumigant suspension due to very minor changes in yield.

Research Needs

The need for additional research is highlighted by the possible loss of soil fumigants. These pesticides are the most effective means of controlling crop-damaging soilborne pests, especially plant-parasitic nematodes and diseases, and to a lesser extent, weeds and possibly insects. There are several interacting factors which influence the need for research should soil fumigants be lost. These include grower needs, the regulatory criteria met or exceeded which endanger cancellation, and the losses caused by these pests not only in the several crops evaluated in this assessment, but also in all other crops grown commercially in the United States.

The values of the several crops in this assessment total approximately $9.8 billion per year, based on values in "Agricultural Statistics 1984"(3). Crop loss figures are difficult to formulate, and must be regarded as estimates based on the first hand experience of production specialists who agree to make these evaluations. The losses associated with soilborne diseases for the crops in this assessment are estimated at $1.36 billion per year in the United States (estimate by Plant Pathology Subpanel, Soil Fumigant Assessment Panel). Nematode damages are estimated in the same crops at $1.0 billion per year (Society of Nematologists (SON) Special Publication No. 1, July 1971, estimated percentages of damages expressed in 1983 values). Further, this SON report estimates that nematodes cause losses in 63 crops grown in the United States, the damages averaging 6 percent in 16 field crops, 12 percent in 23 fruit and nut crops, 11 percent in 24 vegetable crops, and 10 percent in all commercially-grown ornamentals. Based on 1983 values, these damages total approximately $6.9 billion annually.

The loss of methyl bromide would have serious effects in forest nurseries, tobacco seedbeds, and fresh market tomato production where it is a mainstay for weed control. Its loss would increase dependence on costly hand labor.

Based on the needs of growers and an evaluation of comparative efficacies, under practical conditions, of chemical and nonchemical control methods, it appears reasonable that for now and for the foreseeable future, United States agriculture will have to rely on chemical treatments in the field to obtain significant reductions in damages caused by plant-parasitic nematodes, soilborne diseases, and weeds.

A commitment to several complementary research approaches will be necessary to develop new environmentally safe pesticides and new or improved application methods in order to reduce these damages and to enable the maintenance of crop productivity at best practical levels. These needs are:

New safer pesticides - Research must be expanded to devise chemical control measures based in new bioregulator technology, i.e., on chemicals found as nonpolluting natural products, including but not restricted to, molting hormones, juvenile hormones, antimetabolites, hatching stimulants, allelopathic agents, and other compounds found in plant and animal systems. Chemicals would be sought and evaluated for specificity of activity against nematodes, plant disease organisms, and weeds, and for being nonpolluting in groundwater.

The research should include empirical detections and evaluations for new activity in natural products and natural product-based compounds, and studies to determine the activity, modes and mechanisms of actions and fates in the soil of selected candidate compounds. Relations between pesticide activity and chemical structures within groups of related compounds should be exploited to provide clues to new and/or increased activity, and to strengthen capabilities for predicting pesticidal activity in general. Synthesis capabilities should be provided to produce new potentially active compounds for evaluation. Basic research should be expanded to improve understanding of the physiology and biochemistry of nematodes, and disease organisms and their plant hosts to help to accelerate the applied research.

Downward-moving systemics - New more efficient natural product and natural product-based pesticides are needed to enable safe and direct application of chemotherapeutic measures to plants. Research must be expanded in plant physiology to develop an improved understanding of root, foliage, and trunk absorption mechanisms and vascular transport in plants. New improved compounds must be designed that can be absorbed by the plant, move to the vascular tissues and then move downward to the roots where nematodes and disease control must be exerted.

The potential advantages of the results of this research would be reduced needs to expose the large soil masses that support crop plant root systems to pesticides. Lower total dosages per acre, which would be required for control if the plants were treated directly, would thus help contribute to reduced groundwater pollution and reduced dangers of chemical damages to crop plants. Data are also needed on modes of action of experimental downward-moving systemics in plants to identify degrees to which they kill, inactivate, or repel root-damaging nematodes and disease organisms.

Improved pesticides and delivery systems - Generally inadequate residual activity of pesticides is a serious problem of long standing. Virtually all pesticides used in agricultural soils must be applied at dosage rates in excess of actual needs, and it is frequently necessary to use repeated applications for best effects. These excesses are intended to minimize unfavorable effects of losses of active ingredients because of intrinsic instability, unstable formulations, losses to the atmosphere, photo-and/or biodegradation, hydrolyses, excessive leaching, inactivation due to absorption and adsorption, and other phenomena.

One of the research areas that holds out the most promise of reducing the severity of these problems is controlled-release (CR) technology, in long and successful service in fitting pharmaceuticals and veterinary medications for efficient use, but relatively new in its application to agricultural soil pesticide-related problems. Research must be expanded to provide United States Agriculture with pesticides or pesticidal formulations with CR characteristics. Such new materials, combined with needed new and more efficient application methods could result in the reduction of per acre application rates of pesticides, reduced levels of pesticides exposed in the environment per unit of time, reduced loss of active ingredients to nontarget sites, and in the soil profile, and thus, greater efficacy and greater environmental safety.

General Summary

Biologic Assessment

Assessments were made of the impacts that the loss of one or more of four soil fumigants, 1,3-D, methyl bromide, chloropicrin, and metam, alone and in mixtures, may have in the control of plant-parasitic nematodes, diseases, weeds, and insects, that reduce yields and increase costs of production in the six crops that were evaluated. The crops include citrus (seedbed and field), cotton, forest nurseries, potatoes, tobacco (seedbed and field), and tomatoes (seedbed, and field production for fresh market and for processing).

Several chemical and nonchemical or cultural alternatives were considered for use, if these soil fumigants are to be cancelled. The chemical alternatives are three carbamates, aldicarb, carbofuran, and oxamyl, and three organophosphates, ethoprop, fenamiphos, and fensulfothion. The nonchemical alternatives include, but are not limited to, deep plowing, fallow, crop rotation, hand-weeding, and the use of resistant varieties. Impacts were measured by estimating differences in efficacy of alternatives, as expressed by yield decreases or increases, and by changes in related production costs. The impacts detailed in this assessment for these six crops indicate, by implication, the probable effects that the loss of soil fumigants may have on all other commercially-grown crops in the United States where fumigants are used to control soilborne pests.

In agricultural soils, in the field and in seedbeds, all plant-parasitic nematodes targeted for control, with only a few specific exceptions, are in the soil mass. As a result, the primary site for application of nematode and root disease control measures is the soil mass. The number of pesticides registered for use that show practical levels of efficacy in that environment is small, and control is principally dependent on soil fumigants. Thus, the control of crop-damaging nematodes and soilborne diseases would be affected most severely by the loss of 1,3-D, methyl bromide, and chloropicrin, which are registered singly and in several mixtures, as preplant fumigants to fit agricultural soils for the production of a wide variety of crops.

The remaining soil fumigant, metam, also registered for a wide range of preplant uses, does not appear to be a candidate for cancellation because its principal degradation product, methyl isothiocyanate, which is also its active ingredient, is unstable and nonpolluting. It is, also, possibly adaptable to a number of postplant uses when it is applied using chemigation or nemagation technology. It is, however, relatively inconsistent in its activity, and usually is most effective in sites with irrigation capabilities. Because of this limitation, metam is not as versatile or as useful as the other soil fumigants despite its activity against nematodes, plant diseases, and weeds.

Disease control in crop plants is dependent on soil fumigants but less so than nematode control since not all diseases are soilborne or otherwise in the soil mass. However, 1,3-D and methyl bromide control various wilt, collar rot, and root-rot organisms that affect crop roots. These organisms should be suppressed if crop yields and production costs are to be maintained at levels that are practical for the grower. Metam can be used to control certain crop plant diseases but is subject to the limitations discussed above.

Negative impacts due to cancellation of one or more of the soil fumigants used to control nematodes and/or soilborne diseases will affect each of the crops in this study, and also, the numerous other crops grown in the United States, because the nonfumigant alternative pesticides that are available are less effective. Annual crops would show damages, expressed as reductions in yields and increased production costs, most rapidly; damages would escalate with time as the use of the less effective alternatives allow increasingly larger nematode and plant pathogen populations to persist in agricultural soils. Growers of certain crops, probably including potatoes and tomatoes, may be forced to abandon acreage that no longer supports economic crop production and move to other areas.

Perennial crops grow more slowly and may also show symptoms of damage from nematode and soilborne disease infections more slowly. With time, damages would escalate as these infections continue to increase.

It is extremely important that all perennial crops have the advantages of a proper "head start." This is usually accomplished by the use of measures designed to prevent or avoid infections. Citrus, evaluated in this study, may be considered as an example. Preventive measures in seedbeds are costly to apply and maintain but produce vigorous seedlings or rootstocks, free of nematode and soilborne diseases. Preventive measures can also be applied to tree sites in the field or can be applied overall to the field itself to help reduce populations of these damaging pests. These treatments help to support vigorous growth of the new plants in the field and make it possible for them to come into early production. If preventive approaches are followed properly in the seedbed and in the field prior to planting, the damaging effects of nematodes and disease organisms can be zero in the seedbed and minimal in the field, in early stages of tree growth.

At the present time, effective preventive measures rely on soil fumigants. Their loss would create difficult production problems. In seedbeds, where eradication of these soil-inhabiting pests is practical, production would be forced to shift to the use of sterile soil (steam treated) or soilless mixtures as planting media in containers. The containers would have to be maintained on surfaces not in contact with the ground, and would require extra watering and protective shelters such as screen or slat houses. These changes would involve extra costs.

In the field, it would be necessary to adapt nonfumigant pesticides such as the carbamates and/or the organophosphates for use as preplant or postplant treatments in place of preplant fumigation with 1,3-D for overall treatments, and either 1,3-D or methyl bromide for tree sites. The nonfumigants are intrinsically less effective than the soil fumigants because they do not permeate the soil mass by diffusion as the latter can, and because current application technology is not capable of placing them in the soil as uniformly and as deeply as they need to be to exert maximum effect.

Soil fumigants that are effective for weed control are methyl bromide and metam, the former being considered the most effective. Metam's efficacy is limited in the field because of the relative difficulty of obtaining good distribution and activity in the soil.

The loss of these fumigants would have varied effects on weed control depending on the roles of these compounds in production practices. Control of weeds in citrus and in cotton would be unaffected. Loss of metam would have very little impact on potato production because adequate nonfumigant herbicides are available for production of this crop. Loss of methyl bromide would reduce weed control seriously in forest nurseries, tobacco seedbeds, and fresh market tomatoes. Although nonfumigant herbicides are presently used in conjunction with soil fumigation, they would not be adequate, if used alone, to control weeds in these crops.

As a result, a large increase in handweeding would be the only practical alternative to enable the maintenance of yields in these three crops at current levels. Extensive handweeding probably would be impractical and labor could be difficult to obtain for this purpose in the United States. The result would be serious impairment of the production of these crops.

The crops evaluated in this assessment, for the most part, do not have serious soil insect problems. Therefore, soil fumigants are not specifically recommended for their control since the availability of nonvolatile insecticides appears to be sufficient for control purposes. Soil fumigants are primarily used for the control of nematodes, soilborne diseases and, to a limited extent, weeds, while soil insect control is only an indirect benefit.

However, this indirect effect of soil fumigants on soil insects is not fully realized because, to date, there is little or no information on the range of organisms that they control. For example, in Florida, tomatoes may suffer increased damage from mole crickets, rootworm larvae, flea beetle larvae, white fringed beetle larvae, and even termites, if soil fumigants are not used. In North Carolina, damages to tomatoes from wireworm larvae may increase. If soil fumigants cannot be used in tobacco seedbeds, increased damage may occur from wireworms, cutworms, midge larvae, mole crickets, and white fringed beetle larvae.

Fortunately, available nonvolatile insecticides could control potential insect problems which may arise. Therefore, on a national level, the loss of soil fumigants, in the short range, should not have a significant impact on the control of soil insects. The long range impact that the the loss of soil fumigants and the possible increased use of nonfumigant carbamates and/or organophosphates for control of nematodes, soilborne diseases, and weeds, may ultimately have on the control of soil insects that damage crops is speculative.

Estimated losses in each of the crops in this assessment due to combined effects of nematodes, plant diseases, and weeds indicate heavy reliance on soil fumigants. It also anticipates potential increases in production costs and decreases in yields if soil fumigants become unavailable, forcing the use of less efficient control alternatives.

Citrus would suffer significantly. The use of sterile mixes, aldicarb and/or fenamiphos in 26 percent of seedbeds would increase production costs by an estimated $500 per acre. In the field, citrus yields would decrease by an estimated 25 to 30 percent, and such decreases could, with time, possibly escalate to 50 percent in 0.4 percent of the acreage.

Cotton production, in the face of the loss of soil fumigants, would suffer an estimated 3 percent loss in 0.4 percent of its acreage.

Forest nurseries require disease and weed control in 50 percent of planted acreage. As a result of the loss of soil fumigants, there would be no means of controlling diseases and weed control would be dependent on handweeding. As a result, forest nurseries would sustain an estimated 50 percent decrease in yield and an estimated increase in production costs of $350 to $450 an acre.

The 19 percent of potato acreage that requires nematode, disease, and weed control would be dependent on less efficient alternatives for the lost soil fumigants such as carbamates and/or ethoprop, an organophosphate, for nematode control, with no alternatives available for other needs. The use of these nonfumigant compounds would be associated with yield decreases ranging from 15 to 38 percent, with losses escalating as nematode populations continue to escalate.

The loss of soil fumigants promises to have extremely serious effects on tobacco and tomato production. In tobacco, seedbeds would be entirely dependent on organophosphates and cultural practices for nematode control, sterile mixes for control of diseases, and hand labor to suppress weeds. It is anticipated that the use of sterile mixes would entail an estimated $200 per acre increase in production costs. Fifty percent of field tobacco acreage requiring nematode and disease control would also have to rely on the organophosphates and on metalaxyl, with an estimated 4 percent decrease in yield and $110 per acre increases in production costs.

There would be similar problems in 46 percent of tomato seedbeds. Nematode control with ethoprop and sterile mixes would increase production costs by $200 an acre, similar to those projected for other seedbeds in this assessment. Field production in 52 percent of acreage devoted to fresh market would require nematode, disease, and weed control, and 31 percent of acreage used for processing tomatoes would need nematode and weed control. However, weed control by means of napropamide and hand labor would be the only control measures available. Estimated losses, due to the lack of soil fumigants would range from 10 to 66 percent in fresh market tomato production, and from 10 to 19 percent in processing tomatoes.

It should also be noted that growers do not necessarily withstand just a straight percent loss in net return. At some point an individual operation may become unprofitable and thus be closed down. This results in total loss of that producing unit. Hence, there may be a greater impact on total production of the crop than is implied by the estimated percent of yield loss and a total impact on those growers who must close down their operations.

In addition to the crops evaluated in this assessment, there are many other crops, most notably strawberries and wintergrown vegetables, which depend upon fumigation for weed control. There are very few herbicides registered for controlling weeds in these crops and the loss of soil fumigants would result in drastic restrictions in our ability to produce these crops economically in the United States.

Economic Assessment

The greatest economic impacts of fumigant regulation would occur if all fumigants were lost, so that no fumigant could serve as an alternative for any other. Assuming that all soil fumigants were lost, the economic impacts are estimated to be as follows for consumers and producers:

Impacts on consumers would occur through short-term increases in retail prices. The annual average price of the six products studied would rise as follows: fresh tomatoes, by 53 percent; potatoes, by 11 percent; canned tomatoes, by 8 percent; and cigarettes, by 4 percent. The loss of fumigants would have no effect on prices of cotton products, citrus fruit, or frozen juice.

Impacts on producers are complex, because changes in both farm costs of pest control and market prices of farm products may affect a producer's economic position. When the loss of fumigants causes crop yield to fall and total crop output to decline, crop prices will tend to rise, and total revenue received by producers will tend to increase. Conversely, an increase in production tends to bring lower total revenue. Because increases in farm costs (after fumigant loss) of controlling soil-borne pests tend to be substantially less than increases in total revenue received by farmers, on the average farmers growing a crop tend to be better off as a group when there is a yield loss and less total production. However, farmers who formerly used fumigants could be hurt severely by fumigant cancellation.

If all fumigants were lost, producers who formerly fumigated would be affected more than producers who did not fumigate, assuming that the loss of fumigants did lead to a change in crop yield. Those who fumigated would experience the

effects of changed output from their acreage, assuming that planted acreage remains the same both before and after fumigant loss. The effects would include a changed market price for the crop, as well as a changes in pest control cost as farmers adopted alternatives to fumigation for the control of soil-borne pests. By contrast, those producers who did not fumigate would experience the effects of a changed market price, but no yield change nor cost change. As a result, loss of fumigants may, in effect, cause a transfer of income between producers who fumigated and those who did not. Fumigant loss impacts on economic averages or other aggregates for <u>all</u> planted acreage should be interpreted with caution because important differences between economic impact on formerly treated vs. untreated acreage may be concealed by the aggregation.

If all fumigants were lost, the average impacts on producers of the several crops can be summarized as follows: Cotton farmers would not be affected, since very little cotton acreage is treated with fumigants, and minimal yield loss occurs when fumigants are withdrawn. For citrus growers, the impact of fumigant loss would be slight; in dollars the increase in revenue to all growers would be only 1 percent of crop value. However, on that acreage where fumigants can no longer be used to treat for nematodes and diseases around mature citrus trees, yields are projected to decline 25-30 percent in the short run. Over the long run, the decline could be greater. In addition, the loss of fumigants used in about one-fourth of citrus nursery seedbeds could lead to an increase in production costs of about $500 per acre on treated acreage. Of the crops studied in this report, only citrus is a perennial

(tree) crop. Because of that, the long-run impact on the citrus industry in the absence of fumigants could be considerably greater than the minor impact shown by the short-run analysis.

The impact of fumigant loss on tobacco producers would be felt in two stages. First, there would be an increase in production cost of about $200 per seedbed acre at the tobacco seedling stage of production, as sterile mixes, nonfumigant chemicals, and handweeding were used to substitute for fumigant control in seedbeds. Second, at the field stage of production there would be an additional $98 increase in control cost per field acre because of lack of field fumigation. Overall, yield loss on treated acres would be about 4 percent. Considering only the combination of smaller crop, higher market price, and greater control costs, the net impact on tobacco producers would be almost negligible. However, allowing for the fact that farmer returns are tied to the Federal tobacco support program, the impact of fumigant loss would be to subtract the amount of control cost increase from market and program returns to those growers who used fumigants. It is estimated that 100 percent of the tobacco seedbed acreage and 50 percent of the tobacco field acreage is fumigated.

The loss of all fumigants would severely affect growers of forest tree seedlings in both the South and the North. In the South, grower net returns are projected to decline by 39 percent as seedling yields fall by 75 percent on treated acreage. Over 95 percent of tree seedbed acreage is fumigated in the South each year, where seedlings are harvested after one year's growth. In the North, where seedlings can be harvested only after 2 or 3 years' growth, almost all seedbed acreage is fumigated, as in the South, but only

about 23 percent of the acreage is treated in any given year. Thus, the first year after fumigant loss northern tree seedling growers as a group would be better off by about 6 percent of crop value because seedling prices would rise. However, in subsequent years both northern and southern growers would have to incur higher costs of seedbed treatment without fumigants.

In the absence of all fumigants, potato growers in the West (as a group) would experience a 20 percent increase in net revenue, while potato growers in the East (as a group) would show a net revenue increase of 8 percent. On treated acreage, yields would be lower by 20 percent in the West and 34 percent in the East. The decrease in total production would lead to higher prices, resulting in higher revenue. Because the demand for potatoes, like other products in this study, is relatively stable, changes in the quantity supplied can lead to large price swings. The percentage rise in price of western potatoes, however, is greater than the rise in price of eastern potatoes because western supply drops more, since a much greater share of acreage is treated with fumigants in the West. Thus, growers as a group in both the East and West benefit as prices rise and control costs go down, but those in the West benefit more. However, a longer run concern is that the lower control costs are the result of eliminating control of soil-borne potato diseases, an important factor for possible long-term analysis.

Fresh tomato growers (as a group) benefit slightly from increased net revenues of 3 to 4 percent (West and East) as all fumigants are withdrawn. However, these small and similar numbers mask two different situations in the East and West, each of which involves some rather large changes. On treated acreage,

eastern tomato yields decline by 60 percent, leading to sharply lower total production and much higher prices; yet, the greater revenue from these higher prices is almost cancelled out by much higher control costs, since about 63 percent of fresh tomato acreage in the East is fumigated. Among eastern growers, the 4 percent overall revenue increase conceals some very large distributional impacts among growers, especially between those who treat with fumigants and those who do not. In the West, by contrast, only 9 percent of acreage is treated, although on that acreage, yield loss with no fumigation runs to 25 percent and costs of alternative control are considerably higher than with fumigation. As higher prices and control costs are balanced, western growers would come out slightly ahead.

Returns to processing tomato growers in the West would rise by 7 percent of crop value if fumigants were not available, mainly because prices would rise as yields dropped by about 11 percent on treated acreage, and total production declined. Control costs, especially for weeding, would rise too, but not enough to negate the benefits of the price increase. However, the increase in control costs would be borne most severely on those acres--about one-third--actually treated with fumigants and whose control practices were thus affected by fumigant withdrawal.

As a group, growers of citrus seedlings in the West would experience a decline in net revenues of about 5 percent of seedling crop value. Growers' total "net" would fall because, without fumigants, costs of controlling soil pests would rise by more than $500 per acre.

In the East, where almost half of the tomato seedling industry treats with fumigants, as measured by treated acreage, growers as a group would find revenues lower by 11 percent following loss of all fumigants. Yield loss would be severe--a 40 percent yield decrease for those growers whose control practices were affected. For these growers, the higher prices they would receive for seedling transplants would not compensate for higher costs of pest control.

Results involving regulatory actions less drastic than the cancellation or withdrawal of all fumigants are of lesser magnitude than the results above, which are based on hypothetical loss of all fumigants. Results for less drastic regulation range downward from the above impacts to no impact at all for action involving the loss of chloropicrin only.

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DATA SOURCES, ECONOMIC APPENDIX TABLES

Table	Data	Sources
47	Acres planted	[19], [20], [30], [31], [32], [33], [34], [35], [36], [37]
	Acres treated annually	Subpanels of experts
48	Projected change in control cost per acre	Subpanels of experts
49	Projected change in control cost, total	Derived
50	Base year yield	[19], [20], [30], [31], [32], [33], [34], [35], [36], [37]
	Projected percent change in yield	Subpanels of experts
51	Scenario yield	Derived
52	Total production (in specified units)	Derived
53	Base year price, farm level	[19], [20], [30], [31], [32], [33], [34], [35], [36], [37]
	Price elasticity of demand, farm level	[21], [22], [24], [25]
	Projected price, farm	Derived
54	Projected crop value	Derived
55	Projected change in revenue, producers	Derived
56	Retail price, base year	[24],[25],[29],[30]
57	Total production (lbs.)	Derived
58	Projected price, retail	Derived
	Price elasticity of demand, retail level	[24], [25], [26]

APPENDIX A

General Assumptions and Scope

The assumptions used in obtaining or deriving the estimates were as follows:

a. The estimates of projected changes in production costs and yields associated with alternative control options, collected during 1985, represent the "base year" or annual weighted average over the 3-year period, 1982 to 1984. Thus, the derived impacts of a fumigant suspension would likely reflect impacts in a year of typical or normal production rather than a year of abnormally high or low production.

b. For field crops, published 1982-84 data from various U.S. Department of Agriculture reports were used in developing base year weighted averages of acres planted, yield, and farm level prices [20, 31, 32, 33, 34, 35, 36, 37]. For seedlings, the base year estimates were obtained by the subpanel of experts in personal communication with nurserymen [19, 22, 30].

Base year weighted averages of 1982-84 field crop retail prices were obtained from unpublished Bureau of Labor Statistics data [29] and seedling retail prices were obtained by the subpanels in communication with nurserymen [19, 30].

With the exception of cotton and tobacco, farm and retail price elasticities of demand were primarily developed using published sources [21, 26]. Cotton and tobacco price elasticities of demand were estimated by subject matter specialists employed by Economic Research Service, U.S. Department of Agriculture sources [22, 24].

c. Projected changes in treatment, production costs, and yields reflect short-term domestic impacts during the next 12 months. Longer term impacts would require estimates beyond the scope of this study,

including taking account of changes in foreign trade, capital requirements, crop substitution, and regional acres grown of specific crops. Further, long-term estimates entail considerably more uncertainty concerning assumptions of availability of new pesticides and new techniques for controlling pests, and economic conditions that affect demand and supply.

d. Where feasible, projected changes in production costs were primarily derived from the difference between the custom application cost of the base year treatment and the cost using the projected set of alternatives specified in a specific scenario. The selection of the projected treatment alternatives gave primary consideration to the next most frequently used alternatives to the suspended pesticides. In some cases, there were no available feasible alternative control measures, either chemical or nonchemical, to the base year control.

e. The analysis examines seven scenarios of pesticide registration suspensions: (1) 1,3-D singly, and in combination is lost. All other fumigants are available plus alternatives, chemical and cultural, for nematode, disease, weed, or insect control. (2) Methyl bromide (MBr) singly, and in combination, is lost. All other fumigants plus alternatives are available, as in item (1). (3) Chloropicrin singly, and in combination, is lost. (4) Metam is lost. All other fumigants plus alternatives are available, as in item (1). (5) All fumigants are lost, but non-fumigant alternatives are available. (6) All fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control. Organophosphates are available. (7) Metam, chloropicrin, and organophosphates are available. All other fumigants and aldicarb, carbofuran, and oxamyl are lost for nematode control.

f. Due to time and budget limitations, only a small number of the crops affected by the suspended pesticides were included in this study. Six

crops were selected based on a priori estimates of production and control cost impacts on total acres grown--citrus, cotton, forest nurseries, potatoes, tobacco, and tomatoes. A number of crops were not included that could be more severely impacted on a per acre basis.

g. The derived impacts assume no new chemical or nonchemical alternatives or techniques will become available during the time period considered in the analysis.

Obtaining Combined Estimates

The data collected by the four subpanels of biologists reflect projected changes in yield and control cost associated with the seven scenarios of available alternatives used to control either nematodes, weeds, disease, or insects. Procedures were needed to combine each of the data sets to determine the total biological and economic impacts for all pests controlled by the suspended pesticides. These changes in yield and control cost were then compared with 1982-84 base year averages of yields, costs and prices. These procedures are discussed in the following sections.

Change in Acres Treated

As a first step, estimates were made of the acres treated by specific pesticides for control of each of the four classes of pests. Next, the estimates of acres treated by specific fumigants were used to reflect the proportion of total acres planted that were treated for control of each of the pest classes. To combine the estimates of each of the pesticide subpanels to reflect acres treated to control all pests, it was assumed that treatments were made to control a primary category of pests, for example nematodes, and other pests, i.e., weeds, diseases, and insects, were controlled as secondary pests. Control of secondary pests was nested with control of the primary pest, which was defined as the pest with the highest

proportion of planted acres treated. In line with this "nesting assumption," the percentage of acreage representing control of the primary pest was used to represent the proportion of planted acreage for controlling all pests.

Change in Control Costs

Each subpanel acquired information relative to the control of a specific category of soil-borne pests, i.e., nematodes, weeds, diseases, and insects. Based on this information, subpanel members determined the effect of loss of particular pesticides on the cost of control of a specific category of pest. The change-in-cost values cannot be averaged because acreages fumigated for control of specific pests were often different and because fumigation costs were subtracted by each subpanel resulting in multiple subtraction of fumigation costs if results from two or more subpanels were combined.

As with combining panel estimates of acres treated, the method used to combine changes in production costs assumed the acreage treated with each category of pest was nested. That is, all acreage treated for a specific pest was treated also for any other class of pest that had a higher percentage of planted acreage treated. The following abbreviations were used:

F = fumigation cost per acre

M_j = alternative method of control for each j pest class

A_j = alternative control cost per acre for each j pest class,

R_j = percent acres treated with fumigant for each j pest class,

C_j = change in control cost for each j pest class, and

C = estimated average change in production cost per acre for all pest classes.

Further, $j=1...4$ represent the descending order of R_j for the set $[R_{nematodes}, R_{weeds}, R_{diseases}, R_{insects}]$. The resulting ordering carries for all M_j, A_j, and C_j. For example, if the percent of total acres treated was 60 for nematodes, 15 for weeds, 30 for diseases, and 5 for insects, the descending order of R would be $[R_{nematodes}, R_{diseases}, R_{weeds}, R_{insects}]$. Thus all variables with the subscript 1 would contain nematode values, subscripts with 2 would contain disease values, subscripts with 3 would contain weed values, and subscripts with 4 would contain insect values.

The general formula to compute the estimated change in production cost is as follows:

$$(1)\ C = [(R_1-R_2)(A_1-F) + (R_2-R_3)(A_1+A_2-F) + (R_3-R_4)(A_1+A_2+A_3-F) + R_4(A_1+A_2+A_3+A_4-F)]/R_1.$$

The format for presenting data by each panel did not include a place for the cost of alternative control methods (A), but instead included the estimated change in cost (C). Therefore, the A variables in equation 1 needed to be defined in terms of C by use of the equation $C = A - F$. Because each term of the previous equation could be different for each pest class, the equation was rewritten as

$$(2)\ A_j = F_j + C_j.$$

Several problems arise that prevented equation 2 from being directly incorporated into equation 1. First, some alternate methods (M_j) may be identical and thus cost of application would not have to be repeated for the second pest. Second, in some situations where the alternate material was used for more than one pest, the application rates may be different. Finally, the variable F in equation 2 was the cost of application of the fumigant used to control the pest with the largest proportion of acres treated; however, the fumigant may be applied at higher rates for control of

one or more of the other pests.

In order to accommodate these problems, the following conditions and assumptions were made. Where multiple A´s were added together in equation 1, the following term was substituted in the equation:

if $M_1 = M_2$, then the term (A_1+A_2) becomes $MAX\{A_1,A_2\}$;

if $M_1 = M_3$, then the term (A_1+A_3) becomes $MAX\{A_1,A_3\}$;

if $M_2 = M_3$, then the term (A_2+A_3) becomes $MAX\{A_2,A_3\}$;

if $M_1 = M_2 = M_3$, then the term $(A_1+A_2+A_3)$ becomes $MAX\{A_1,A_2,A_3\}$; etc.

Not all possible conditions were elaborated here; however, it can be seen that where alternate control materials were identical (actually or functionally) within a group, only one application cost was factored into the equation, and this cost was the largest among the set of possible alternative control costs.

Similarly, each F term in equation 1 was defined as the maximum of all F´s available in each grouping with the equation, i.e. the first F is F_1,

the second F is $MAX\{F_1,F_2\}$,

the third F is $MAX\{F_1,F_2,F_3\}$, and

the fourth F is $MAX\ \{F_1,F_2,F_3,F_4\}$.

Equation 1 can be rewritten as

$$(3)\ C = [(R_1-R_2)(A_1-F_1) + (R_2-R_3)(A_1+A_2-MAX\{F_1,F_2\}) + (R_3-R_4)(A_1+A_2+A_3-MAX\{F_1,F_2,F_3\}) + R_4(A_1+A_2+A_3+A_4-MAX\{F_1,F_2,F_3,F_4\})]/R_1$$

where, within a group of A variables (e.g. $A_1+A_2+A_3$), if any of the alternate control materials are the same (actually or functionally), the corresponding A_j´s are replaced with a single A_j.

This procedure thus allowed the combining of production costs for the

four classes of pests by taking into account (a) the subtraction of each set of alternatives from the base year cost, and (b) the nesting assumption.

Change in Yield

A change in production practice by use of an alternative pest control method usually resulted in a change in expected yield. Subpanels estimated changes in yield for each of the four pest categories. When a change in yield was expected, compared with the base year yield, the change could result in a yield increase (positive change) or decrease (negative change or loss). Thus, it was possible to have four simultaneous yield change estimates (nematode, disease, weed, and insect) for one alternative control method.

Very little methodology is available for combining estimates of individual pest losses into a single, multiple-pest loss estimate. Ortish (1952) pointed out that adding changes in yield introduces statistical error, namely an exaggeration of the losses to the extent that they can exceed 100 percent.

The method of multiple pest estimation we have chosen was originally used by Padwick (1956) to estimate plant disease losses in tropical and subtropical regions. The method assumes independence between pests in that crop losses due to one pest are considered to affect the crop independently from other pests. This would be true if only one type of pest attacks a site on a crop (e.g., a lesion-forming plant disease cannot occupy the same site that a foliage-feeding insect has previously eaten). However, the assumption does not hold up when pest effects are systemic within the plant, or when the crop is stressed by factors such as weed competition. The nesting assumption used in determining acres treated and control cost assumed crops were treated to control a primary pest and control of secondary pest was nested within that control. To the extent that the site of damage is independent between

pests, this assumption is not violated. Unfortunately, few models currently exist to combine interacting or synergetic losses from individual pests into a single multi-pest loss estimate for the crops included in this study.

Past pesticide registration suspension studies have generally focused on yield impacts with the suspension of a single pesticide. Summing the yield impacts reflected in several studies, one detects considerable bias if the total yield impacts approach or exceed 100 percent of total production. In spite of the limitations of the Padwick model, it does have a major advantage in that the model reduced the potential bias of inadvertent exaggerated loss estimates. Using this model, the combined yield loss estimate due to multiple pests could never exceed 100 percent of total production.

The model is expressed in the following form:

(1) $_{Lt} = 100[1-[(1-L_n/100)(1-L_w/100)(1-L_d/100)(1-L_i/100)]]$

where

L_t = estimated percentage yield change, all pests,

L_n = estimated percentage yield change, nematodes,

L_w = estimated percentage yield change, weeds,

L_d = estimated percentage yield change, diseases, and

L_i = estimated percentage yield change, insects).

L_n, L_w, L_d, and L_i represent weighted yield changes based on acreage treated. For example, $L_n = (R_n . Y_n)/100$, where R_n is the percentage of total planted acreage treated for controlling nematodes and Y_n is the percentage yield change on those acres.

In order to more accurately determine the combined yield changes, the calculated yield change for multiple pest situations should reflect the proportion of the crop acreage that is affected by the pest. As in the

computations for "change in production cost," we assumed that the smaller pest effects were nested in the larger effects. If the combined yield changes are designated L_j, where j represents the ordered yield change values, as described in the previous section, then the following equation will compute the corrected percent yield change for acreage treated to control one or more pests,

$$(2)\ L_t=[(R_1-R_2)(L_1)+(R_2-R_3)(L_{12})+(R_3-R_4)(L_{123})+R_4(L_{1234})]/R_1$$

where L_t is the corrected percent yield change in treated acreage, R is the proportional acreage treated for each of the 4 pest, and L is the combined yield change for pests where the subscripts represent the combined yield changes for pest 1, pest 1 and 2, pest 1, 2, and 3, and pests 1, 2, 3, and 4, respectively.

Equation (2) can be modified to compute the corrected yield change in all crop acreage by removing the denominator for equation (2),

$$(3)\ L_a=[(R_1-R_2)(L_1)+(R_2-R_3)(L_{12}))+(R_3-R_4)(L_{123}))+R_4(L_{1234})]/100$$

where L_a is the corrected yield change for all acreage within a region and the other terms are as described above.

APPENDIX B
Price Elasticity of Demand and Farm-Level Prices

A brief review of the concept of price elasticity of demand may be useful here. A price elasticity of demand is a value which measures the change in the quantity of a product a purchaser is willing to buy when the price of that product changes. The elasticity value expresses the percentage change in quantity purchased when there is a (or for each) 1 percent change in price. Conversely, the reciprocal of the elasticity value helps to measure the change in the price of a product when there is a change in the quantity of that product supplied to the market. This reciprocal of the demand elasticity, called "price flexibility", when multiplied by any percentage change in quantity supplied, expresses the short-run percentage change in market price which occurs in response to the short-run change in supply. (John W. Goodwin, Agricultural Economics, Prentice Hall, 1977. Chapter 12.)

Our estimates of change in price in response to change in quantity supplied (because of a scenario action which decreases crop yield) are of critical importance to the economic assessment in this report. In the calculations in this report, an estimated change in price of a crop leads to an estimated change in revenue to producers of that crop, and then to the estimates, by scenario, of the change in total revenue to all producers of the six crops studied. Since much hinges on the elasticity values, it is important to document the sources or estimating methods for the elasticities cited in Table 53.

The two published sources for certain of the elasticity values (as explained further below) are: Kuo S. Huang, U.S. Demand for Food: A Complete System of Price and Income Effects, Technical Bulletin 1714, Economic Research Service, U.S. Department of Agriculture, December 1985; and P.S. George and G.A. King, Consumer Demand for Food Commodities in the United States with Projections for 1980, Monograph No. 26, Giannini Foundation, University of California at Davis, 1971. However, in no case has it been possible or desirable simply to copy any of the elasticity values in those reports directly into Table 53. Adjustments were needed for various reasons with respect to elasticity values for citrus (field), potatoes, tomatoes (fresh-field), and tomatoes (processing). (Elasticity values for the other crops cannot be found in either of the two above sources, and are estimated differently, as explained below.)

Huang's work, while recent, calculates elasticities only at the retail level; George and King's work, while calculating elasticities at both the retail and farm-gate levels, is 15 years old. For Table 53 it seemed preferable to start with Huang's values applying to retail markets, and adjust them to apply to farm-gate markets (that is, to the market represented by the initial sale by the farmer to the first intermediary in the marketing chain from farm to consumer). The adjustment of Huang's values from retail to farm level is made in accord with the procedure and the specific ratios of farm-level elasticities to retail-level elasticities found in George and King for oranges, potatoes, tomatoes-fresh, and tomatoes-canned. However, Huang's elasticity values for oranges and grapefruit first had to be averaged, with weights assigned according to an estimated 74 percent of the citrus market for oranges and 26 percent for grapefruit. (Elasticity data for lemons were not available.)

Farm level elasticity values for cotton are based on personal communication from cotton analyst Edward Glade, ERS, USDA, and for tobacco on personal communication from tobacco analyst Verner Grise, ERS, USDA. There are no known published sources for farm-level elasticities for seedlings of the following: citrus trees, tobacco, tomatoes, and forest trees; therefore, the elasticity values for these seedling crops entered in Table 53 are judgmental, based on conversations which author Walter Ferguson had with biological panel members taking part in this assessment and who were most familiar with the crops in question.

Once the farm-level price elasticities of demand have been estimated and entered into the data base, the farm prices, by crop, shown in Table 53 are each calculated according to the following formula:

$$P_{1....7} = P_o \left[1 + \left(\frac{\left(\frac{1}{e}\right) \Delta S_{1....7}}{100} \right) \right]$$

where $P_{1....7}$ = Projected price under each scenario, 1 to 7

P_o = Price in base period

e = Price elasticity of demand at the farm level

$\Delta S_{1....7}$ = Percentage change in quantity supplied of the crop from base period to scenario period, 1 to 7

APICULTURE

BIOLOGIC AND ECONOMIC

ASSESSMENT OF

APICULTURE FUMIGANTS

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BIOLOGIC AND ECONOMIC ASSESSMENT OF APICULTURE FUMIGANTS

Introduction

Honey bees, being social insects, maintain colonies that are normally composed of one queen, from 5,000 to 60,000 worker bees and from none to several hundred drones. The bees construct wax combs which are used for food storage and brood rearing. Honey bees utilize both honey (carbohydrate source) and pollen (protein source) to maintain the colony. Honey stored in excess of the needs of the colony can be removed by the beekeeper for his own use. The worker bee develops from an egg deposited by the queen in a cell of the comb. Three days later the egg hatches into a larva which is then intensively fed by adult bees for 6 days. The cell is then sealed, and the larva changes into a pupa and emerges from the cell as an adult bee 21 days after the egg was laid. Drone bees require 24 days and queens 16 days to develop from egg to adult.

Honey bees are kept in all 50 States; however, commercial honey production is generally concentrated in about 20 States. Of the estimated 4.1 million colonies in the United States, half are owned and operated by about 1,600 commercial beekeepers (300 or more colonies) and the other half is owned by an estimated 200,000 hobbyists (1 to 24 colonies) and 10,000 part-time beekeepers (25 to 299 colonies) (8).

The honey bee industry produces honey and beeswax, queens, package bees and also provides pollination services. Honey production is the primary income source for the industry. In the United States, honey bees annually produce over 200 million pounds of honey, valued at about $130 million per year. Beeswax is produced coincidentally with honey; U.S. production averages about 3.5 million

pounds annually, valued at about \$5.2 million per year (7). The economic value of bee pollination to crop producers, however, far exceeds the total revenue of the beekeeping industry from all other sources. In the United States, over 90 crops valued in excess of \$18 billion, require or are benefited by bee pollination (2).

Beekeeper's losses resulting from honey bee diseases and pests are difficult to assess. Losses are reflected in decreased honey and beeswax production, fewer colonies for pollination, and increased operating costs. In addition, States spend thousands of dollars annually to enforce laws and regulations designed to control bee diseases, primarily American foulbrood (AFB). The authority for the destruction of AFB-diseased colonies is included in most State laws.

The greatest damage to honeycombs is caused by the greater wax moth (GWM), *Galleria mellonella* (L.). A number of other moths damage honeycombs, but to a lesser degree. The GWM is found everywhere honey bees are maintained; however, the damage is greatest in the Southern U.S.

The GWM can be a problem in hives that have small populations of adult bees, such as those used for queen production. The GWM can also damage honeycombs in colonies where the normal adult population has been reduced by pesticide damage, disease, winter losses, etc.

To prevent or reduce losses from GWM caused by lack of bees, beekeepers store hive equipment from such colonies in storage structures. Also, empty honeycombs, after extraction of honey, are stored over winter and frequently damaged by the GWM. It is these honeycombs in storage that need the protection of fumigants.

Four fumigants have been or currently are being used in apiculture (Appendix 1). These include ethylene oxide (EtO), which is used to control bee diseases; ethylene dibromide (EDB), paradichlorobenzene (PDB) and aluminum phosphide (ALP) which are used to control the greater wax moth (GWM). However, EtO is currently under Special Review with label amendments scheduled for FY-86, and EDB was voluntarily cancelled by the registrant in January 1985 with sale of existing stocks allowed until February 1986.

Use of Pesticides in Apiculture

Ethylene Oxide

Ethylene oxide is a biocide that kills essentially all life forms (at appropriate doses). Fumigation of bee equipment with EtO is a valuable tool in the prevention and control of bee diseases. It is used primarily as an alternative to burning bee equipment that may be contaminated with *Bacillus larvae*, the causative agent of AFB. Since pure EtO is extremely flammable, it is mixed with either CO_2 or flurocarbon 12 to eliminate the flammability. Both formulations are used in bee equipment fumigations.

The fumigation procedure generally consists of loading the chamber with bee equipment, sealing the door, and evacuating to 26 inches of mercury. A measured quantity of EtO (450 to 700 mg per liter of chamber space) is then introduced and the chamber is operated for a specified period at approximately 100 F. The chamber is re-evacuated to 26 inches of mercury, vented to atmospheric pressure then opened. The equipment is removed and aerated for a minimum of 24 hours in either a well-ventilated, unoccupied room or in the open (5). In normal usage, the chance for operator exposure to the fumigant is minimal for commercially built EtO chambers. Operator exposure to EtO could occur while unloading the fumigation chamber or from entering the room where equipment is being aerated.

Ethylene oxide usage for control of bee diseases is summarized in Table 1. An estimated 1,500 pounds of EtO are used to fumigate hive equipment.

Table 1. Summary of annual EtO use for bee disease control in the United States.

State	Pounds EtO
AL	35
CT	40
DE	14
ME	150
MD	105
MI	287
NH	50
NJ	140
NY	50
NC	70
TN	168
VA	150
WA	50
WV	150
	1459

In States where EtO fumigation is available, apiary inspectors have found that beekeepers are more cooperative toward disease control programs, because inspectors are no longer required to destroy their diseased equipment. Diseased hives and equipment which previously would have gone undetected are being brought to the apiary inspector's attention.

Ethylene oxide fumigation to recycle hive equipment from AFB-infected colonies has other benefits. In addition to destroying *B. larvae*, EtO also kills the causal organisms of European foulbrood (EFB), chalkbrood, and nosema. Also, tests indicate that colonies placed in EtO-fumigated hives develop larger populations due to controlling unknown diseases of honey bees (3).

Controlling AFB is a local option; as such, it is subject to laws and regulations of the various States (4). Some States permit the use of antibiotics to treat diseases. Others forbid antibiotic use and require the destruction of the hive equipment by burning or decontamination. In some areas, EFB is treated similarly when found.

Oxytetracycline (OTC) use for the prevention and control of AFB or EFB is a practical measure and in some instances quite desirable; however, using antibiotics to eradicate these diseases is generally not effective as OTC does not kill the causal organisms. Disease development is controlled only while the antibiotic is present in the larval food. Also, apiculturists disagree on the value of antibiotics for the treatment and (or) prevention of bee diseases. There is also concern about the use of antibiotics and the possibility of selecting a strain of drug-resistant bacteria, making disease control more difficult.

Gamma or high-velocity electron beam radiations are technically feasible alternatives to EtO fumigation (1,6). To be economically feasible, however, large amounts of bee equipment must be collected and transported to the radiation facility. Furthermore, only a limited number of radiation facilities are presently available.

There are no satisfactory alternatives to EtO for fumigating bee hive equipment for disease control. In general, the States using EtO provide this service at a minimal cost, with the beekeeper paying only for the gas (approximately $4.00 per hive). The operator of the fumigator is, in most cases, a State-paid regulatory official.

Ethylene Dibromide

Until recently, most of the 1,600 commercial beekeepers (over 300 colonies) in the U.S. used EDB (85% a.i.) to fumigate empty honeycombs. Ethylene dibromide destroys all life-stages of the GWM (eggs, larvae, pupae, adult). Over the last few years EDB use has decreased; last year (1985) no EDB was sold by any bee supply house for GWM control. It is quite likely that all supplies of EDB will be expended by the end of 1987. At its peak, an estimated 20,000 lb of EDB was being used by sideline and commercial beekeepers annually.

When no fumigation chamber was available, beekeepers placed stacks of hive bodies (8 supers) out-of-doors and away from occupied buildings. An absorbent material, such as a towel or cloth, was placed on the top of each stack, 10 g (1 teaspoon) of EDB placed on the cloth and the entire stack was covered with a plastic sheet and fumigated for 24 hours. At temperatures lower than 15°C (60°F), dosage was doubled. When a fumigation chamber was available, the dosage was 2 lb/1,000 ft^3. In either case the minimum exposure time was 24 hours. Normally, beekeepers needed to treat their equipment only once a year, just prior to winter storage.

Ethylene dibromide was not used for combs containing honey for human consumption. Beekeepers were cautioned about the hazards of dermal contact and vapor inhalation, and this decreased the use of this chemical.

The registrant of EDB requested voluntary cancellation of registration in January 1985 (10). EPA established the effective cancellation date as February 1, 1985 and determined that the sale and distribution of the product if produced on or before the effective date of cancellation could legally continue in commerce until the supply was exhausted, or for one year after the effective date of cancellation, whichever was earlier. EDB could, therefore, no longer legally be sold for bee equipment fumigation after February 1, 1986.

Paradichlorobenzene

Because EDB is no longer available to control GWM, the material of choice appears to be PDB. Last year about 61,500 lb. of PDB were used to treat approximately 1,722,000 hive bodies of combs in this country. Paradichlorobenzene is available as a solid crystal that evaporates slowly, releasing the active ingredient as a gas. This material like EDB can only be used for empty combs. Because PDB does not destroy GWM eggs, the crystals must be replenished periodically.

Paradichlorobenzene is generally used in stack of hive bodies (up to 5 full-depth supers). All cracks should be sealed with tape. Three ounces (85 g) of PDB crystals are placed on a piece of paper on the top of the highest hive body. The stack of hive bodies should then be covered with an outer cover of a hive. For PDB to be effective, the ambient temperatures should exceed 21°C (70°F). Every 2-3 weeks the beekeeper must examine the supply of PDB and replenish as needed.

Aluminum phosphide

Very limited amounts of ALP have been used to control GWM. The amount used is estimated at less than 100 lb/yr. The dosage for the control of the GWM is 30-45 tablets or 165 pellets per 1000 ft^3. (approx. 49 to 74 g a.i.). The actual fumigation period varies from 2-4 days depending on the temperature.

Economic Assessment

There are no alternatives for EtO fumigation to decontaminate AFB-contaminated equipment. Other potential methods are being developed. If EtO was not available to beekeepers, an estimated 11,500 hives would be destroyed by burning each year. The replacement cost of this bee equipment, if new, would be $862,000 (Appendix 2) and the net loss of banning EtO would cost beekeepers $793,000 (replacement cost minus treatment cost savings). Fumigation with EtO is conducted under authority of State 24c labels[1/]; consequently each state maintains rigid controls on its use.

[1/]State registrations for meeting special local needs in accord with the provisions of the FIFRA.

The panel estimates losses caused by the wax moths, even using present fumigants, exceed $6,000,000 annually (Scenario I) and without any fumigant, annual losses would be approximately $34,000,000 (Scenario V). The net loss of cancelling all fumigants would be approximately $27.8 million (Appendix 3). These are serious losses considering that the value of the bee colonies in the U.S. is about $250 million (Appendix 4) and that the estimated total revenues of the beekeeping industry is about $195 million annually--$135 million for honey and beeswax, $30 million for paid pollination and $30 million for queens and package bees. EPA estimated the annual economic benefits of EDB for beehive supers to be $10 million (9).

Scenario I: Wax Moth Damage-Current Use

		Costs			
Material	Supers treated	Materials	Labor	Losses despite treatment*	Total
EDB	2,296,000	$ 9,480	$22,960	$3,444,000	$3,476,440
PDB	1,722,000	193,725	34,440	2,583,000	2,811,165
ALP	82,000	1,312	1,640	123,000	125,952
Total	4,100,000	$204,517	$59,040	$6,150,000	$6,413,557

* Estimated that 10% of supers are lost.

When EDB is no longer available to beekeepers, it is likely that the material of choice will be PDB. However, its use requires more labor input to inspect for damage and to check for the presence of PDB crystals. With EDB, usually only one inspection was necessary. Thus, it is the opinion of this panel that the non-availability of EDB will cause an increase in the cost of labor of $272,000 (Appendix 3) but the resultant losses to GWM will remain the same (Scenario II).

Scenario II: Current Registrations, EDB Supplies Expended

Material	Supers treated	Costs: Materials	Labor	Losses despite treatment*	Total
PDB	4,018,000	$452,025	$80,360	$6,027,000	$6,559,385
ALP	82,000	1,312	1,640	123,000	125,952
Total	4,100,000	$453,337	$82,000	$6,150,000	$6,685,337

* Estimated that 10% of supers are lost.

The loss of both PDB and EDB would leave only two registered alternatives, ALP and *Bacillus thuringensis* (BT) (Scenario III). Net losses would increase by about $260,000 over current use but would be about $15,000 less than the losses after EDB supplies are expended (Appendix 3). However, this estimate does not include cost of securing pesticide applicator licenses and cost of upgrading buildings to make ALP fumigation feasible and legal. Commercial beekeepers who own 75% of all the combs would most likely not consider BT as an alternative. However, the hobbyist who owns the remaining 25% of the combs would use BT if no fumigants were available. ALP would not be a satisfactory alternative for hobby beekeepers because they would have to truck their equipment to fumigation chambers. Fumigation chambers that use aluminum phosphide must be gas-tight to maintain adequate fumigant concentration for at least two days. In addition, having ALP as the only registered alternative would impose added hardship on beekeepers because it is the only material currently registered that is available only to licensed pest control operators. If only ALP were available, beekeepers would have to either have all fumigation done on a custom basis by licensed operators or secure a license for one of the company's employees.

Scenario III: PDB Registration Cancelled

Material	Supers treated	Materials	Labor	Losses despite treatment*	Total
		Costs			
ALP	3,075,000	$ 49,200	$61,500	$4,612,500	$4,723,200
BT	1,025,000	410,000	0	1,537,500	1,947,500
Total	4,100,000	$459,200	$61,500	$6,150,000	$6,670,700

* Estimated that 10% of supers are lost.

With the loss of both EDB and ALP beekeepers would most likely switch to PDB (Scenario IV). The losses would increase by approximately $280,000 over current use and by about $8,000 after EDB supplies are expended (Appendix 3).

Scenario IV: ALP Registrations Cancelled

Material	Supers treated	Materials	Labor	Losses despite treatment*	Total
		Costs			
PDB	4,100,000	$461,250	$82,000	$6,150,000	$6,693,250

* Estimated that 10% of supers are lost.

Scenario V: All Fumigants Cancelled

Material	Supers treated	Costs: Materials	Labor	Losses despite treatment*	Total
BT	1,025,000	$410,000	0	$ 1,537,500	$ 1,947,500
None**	3,075,000	0	0	32,287,500	32,287,500
Total	4,100,000	$410,000	0	$33,825,000	$34,235,000

* Estimated that 10% of supers are lost.

** Estimated 70% loss if no treatment.

Research Needs

Aside from the obvious need to develop alternatives to the presently used fumigants, research should be conducted to increase operator safety as well as protecting the consumer. In the case of EtO, most of the fumigation is done outdoors. However, there are three problem areas that need monitoring and may require modification of the present procedures:

1. Since operator exposure while loading and unloading the fumigation chamber could exceed current OSHA time-weighted average, respirators may need to be a requirement. EtO chambers being used for fumigating bee equipment should be studied to perhaps increase "air-washes" to reduce operator exposure.
2. The aeration of bee equipment following fumigation should also be studied. Circulating fans, room temperature, a monitoring device, and a respirator should be evaluated as aids to reduce the potential operator exposure during aeration.

3. Methods should be developed to determine whether EtO can be found in beeswax.

The loss of ethylene dibromide creates a serious problem for beekeepers. Since no satisfactory alternate fumigant is available for the control of GWM, research must be instituted immediately. One fumigant that has been used in the past and should be reevaluated is calcium cyanide.

Summary

Four fumigants have been or are currently being used in Apiculture. These include ethylene oxide (EtO), which is used to control bee diseases; ethylene dibromide (EDB), paradichlorobenzene (PDB) and aluminum phosphide (ALP) which are used to control the greater wax moth (GWM).

Annual EtO usage for control of bee diseases is estimated at 1,500 pounds and the equipment thereby salvaged would cost beekeepers in excess of $862,000 to replace. Fumigation with EtO is conducted under authority of EPA 24c labeling; consequently each state maintains rigid controls on its use. There are no satisfactory alternatives to EtO for fumigating bee hive equipment for disease control.

It is no longer legal to sell or use EDB for controlling GWM. Until recently, most of the 1,600 commercial beekeepers (over 300 colonies) in the U.S. used EDB (85% a.i.) to fumigate empty honeycombs. A few years ago, an estimated 20,000 lbs of EDB was being used by sideline and commercial beekeepers annually. Over the last few years EDB use has decreased; last year (1985) no EDB was sold by any bee supply house for GWM control.

When current supplies of EDB are expended, PDB will become the predominant fumigant for controlling GWM, increasing beekeepers costs and losses by about $270,000 annually. If PDB is cancelled, users will switch to BT and ALP, decreasing costs and losses by $14,687. This decrease in cost does not take into account the extra costs to commercial beekeepers to secure pesticide applicator licenses and to upgrade storage buildings to make ALP fumigation feasible and legal.

If PDB and ALP registrations are cancelled, no fumigants remain. Only BT, a microbial insecticide, would be available. Under these conditions, costs and losses are expected to increase by $27.5 million over costs and losses using currently registered materials.

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Appendix 1

Availability, Cost, Efficacy and Registration Status of Fumigants used in apiculture

Fumigant	Availability	Cost	Efficacy	EPA Restricted Use
Ethylene dibromide (EDB)	No[1/]	Low	Excellent[2/]	No
Paradichlorobenzene (PDB)	Yes	Low	Good[3/]	No
Aluminum phosphide (ALP)	Yes	High	Excellent[2/]	Yes
Ethylene oxide (EtO)	Yes	High	Excellent	No

1/ Registration of EDB was voluntarily cancelled in January 1985.

2/ All life-stages of the greater wax moth are destroyed.

3/ Greater wax moth eggs are not destroyed.

Appendix 2

Replacement Cost For Loss of Ethylene Oxide

1. Estimated number of hives fumigated = 11,580 hives.1/
2. Cost of replacement hive (new) = $ 75.002/

   11,500 @ $75 = $862,000
3. Cost of fumigation: 11,500 hives x 3 boxes per hive @ $2.00/box = $69,000
4. Net savings: Replacement cost $862,000

   \- Fumigant cost 69,000

   $793,000

1/ Source: 1985 survey of States by Assessment panel.

2/ Three full depth hive bodies @ $4.00 = $12; top & bottom @ $3.50 = $7; 27 plastic foundation @ #1.25 = $33.75; nails, paint, labor @ 25% of base equipment cost ($53) = $13.25; freight @ 20% woodenware & foundation = $10.55; total = $77.17. Rounded to nearest $5.00 is $75.00 per hive.

Appendix 3

Wax Moth Damage Scenarios

Net Economic Impact on Beekeepers from Cancelling Fumigant Registrations

Net Losses from Change to Other Scenarios

Baseline	II	III	IV	V
Scen. I 1/	$271,780	$257,143	$279,693	$27,821,443 2/
Scen. II	NA	-14,637 3/	7,913	27,549,663
Scen. III	NA	NA	22,550	27,564,300
Scen. IV	NA	NA	NA	27,541,750

1/Scenarios reflect loss of pesticides as follows: (II) EDB, (III), PDB, (IV) ALP, (V) All fumigants

2/e.g., total losses Scenario V - total losses Scenario I

$34,235,000 - $6,413,557 = $27,821,443

3/This shows beekeepers would gain a net of $14,637 if PDB is lost; however, this does not include cost of securing pesticide applicator licenses and costs of upgrading buildings to make ALP fumigation feasible and legal.

Appendix 4

Cost Work Sheet

Value of Combs

4.1 million honey bee colonies

@ 4 supers per colony = 16.4 million supers

@ 10 combs per super = 164 million combs

Total value of combs = 164 x $1.50 = $246 million

Wax Moth Damage

From September to April

Approximately one-half of the combs (82 million) are stored and the other one-half (82 million) remain on active colonies (not stored).

Of the 82 million stored combs, 41 million are fumigated while in storage and the remaining 41 million combs (not on hives) are stored in unheated buildings and not fumigated. The latter procedure of storing combs without fumigation can be used in the north where the winter temperatures are low enough to retard or prevent the development of the GWM.

Therefore, without fumigants only the 41 million combs that are treated would be vulnerable to damage. It is the opinion of this panel that 70% of these combs would be destroyed without fumigation (28,700,000 x $1.50 = $43,050,000 damage).

From May to August

There is wax moth damage to combs; however, since no fumigant is used during this period, the effect of eliminating the use of fumigants will not impact on beekeepers.

Appendix 4

Labor

Costs are assumed to be \$0.02/super-treatment (PDB treated twice/yr; all others once/yr).

Costs of Fumigants

PDB 61,500 lbs used x 16 oz = 984,000 oz

3 oz PDB used to treat 50 combs

$$\frac{16,400,000 \text{ combs treated with PDB}}{50} = 328,000 \text{ treatments needed}$$

328,000 x 3 oz = 984,000 oz

$$(2 \text{ treatments per year}) \frac{(0.1875 \text{ lb})}{5 \text{ supers}} (\$1.50/\text{lb}) = \$0.1125/\text{super-yr.}$$

EDB \$1.50 lb of EDB 80 combs treated 10 g/trt.

$$\frac{22,960,000}{80} = 287,000 \text{ trt. } 287,000 \times 10 \text{ g} = 2,870,000 \text{ g}$$

$$\frac{2,870,000}{454} = 6,320 \text{ lb EDB} \times \$1.50 = \$9,480 \text{ cost of EDB}$$

Appendix 4

ALP 820,000 combs x 0.10 = 82,000 supers x 2 cu. ft./super = 164,000 ft^3

164 trts. at 165 pellet/trt.

27,060 pellets

$\frac{(\$0.01)}{Bu} \left(\frac{Bu}{1.244\ ft^3}\right) = \$0.008038/ft^3$ x 2 ft^3/super = \$0.0160/super

BT \$1.00/2.5 supers = \$0.40/super

STRUCTURES

BIOLOGIC AND ECONOMIC ASSESSMENT

OF

STRUCTURAL PEST CONTROL FUMIGANTS

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BIOLOGIC AND ECONOMIC ASSESSMENT OF STRUCTURAL PEST CONTROL FUMIGANTS

Introduction

There are several destructive pests of structures. To eliminate these pests, the practice of fumigation is required. These pests are primarily insects and wood destroying by nature. In addition, there are other insects and vertebrate pests that occasionally present a problem which can be eliminated quickly and efficiently by the application of a fumigant to the structure.

Pests

The pests for which fumigation is primarily used as a control measure are in two insect orders, the Isoptera (termites) and the Coleoptera (beetles).

Termites

There are two termite species for which fumigation is used, the drywood termite (Kalotermitidae) and the Formosan subterranean termite (Coptotermes). The drywood termites infest structures along the southeast, Gulf and west coast areas of the United States. They are also a problem in Puerto Rico. These termite colonies do not need soil moisture or contact. They develop small colonies, but because they swarm inside a structure, many colonies can be located throughout the building. Left uncontrolled, significant damage can result.

These termites have also been found in other areas of the United States, probably shipped in building materials from the southeast. Occasionally, they present a problem in structures in other areas of the country.

The Formosan termite is similar in habits to the more typical subterranean termite. The colony is usually located in the ground, but it is very common for the colony to have extensive above-ground workings, including the construction of "carton," a nest-like structure above ground. This, plus the fact that these termites have very large colonies, (over one million individuals) presents a formidable control problem. Soil treatments do not always suffice. These termites are stronger fliers than other subterraneans and can infest large structures from the roof if adequate moisture is present. They are the principle termite species in Hawaii and are located in several areas of the south in mainland United States (Charleston, S.C.; Miami, Fla.; New Orleans and the Houston-Galveston areas). It is estimated that 25 percent of the high-rise structures in Hawaii, and up to 10 percent of similar structures in Florida (Dade County area), are infested from the roof area (3). Left uncontrolled, these termites can destroy a structure in a matter of years.

The Formosan termite has been established for many years in the mainland United States; although their spread has been minimal, they are known to thoroughly infest many landmarks and historic buildings in Charleston and New Orleans.

Beetles

There are numerous beetle species that infest wood in structures. The most common groups are the Anobiid and Lyctid, powder post beetles and one species of Cerambycid (longhorn borer) beetle.

The Anobiid beetles, sometimes referred to as deathwatch beetles, can infest houses across the United States. They primarily infest structural support timbers, which makes them particularly damaging. Their life cycle may vary from 1 to 3 years, depending on species and a variety of environmental factors. The eggs are laid in crevices in the wood, larvae hatch and tunnel into the wood feeding on various nutrients. As the name implies, the frass of these beetles resemble powder. Many infestations remain undetected for many years; the resulting damage can result in the collapse of support beams and structural timbers.

Lyctid beetles are most common in the southeastern United States. They commonly infest the harder wood species such as oak, ash, etc., and can be very damaging to art and finished objects in a structure. The life cycle lasts for 1 to 2 years, depending on species. Because of the types of wood they infest, the Lyctid can be very damaging.

The other major wood destroying beetle is a Cerambycid, the old house borer. This large beetle is most common in the United States, east of the Mississippi River. The beetle usually infests structural timbers in the attic, crawl, and basement areas. The larvae may live for 3 to 15 years before emergence as an adult. These beetles, as the Anobiid and Lyctid, can reinfest if conditions are favorable.

There are numerous other pests for which fumigants can be used. Cockroaches, mice, rats, and carpet beetles (Dermestid) are the most common "other" insects for which structural fumigation can be effective.

Pest Control

Control of these wood destroying organisms can be costly and include extensive repairs. In general, the only sure method of killing the larvae and eggs of these insects is through fumigation.

Fumigants

There are presently two fumigants used to fumigate structures infested with drywood termites and the various beetles listed above. The two fumigants are sulfuryl fluoride (Vikane™) and methyl bromide (Brom-o-Gas™ and Metabrom™ are two common products). A third fumigant, chloropicrin, is also used as a warning agent when fumigations are performed.

Considering the pests and their distribution, fumigation is common in the southeast, along the Gulf coast, and the southwest, including Southern California. The majority of these fumigations are for drywood termites. Fumigation for Formosan termites is common in Hawaii and becoming more common in the mainland United States. This process is necessary when an infestation persists or the structure is such that it dictates this method, i.e., roof infestations. Fumigations for beetles take place along the east coast, including the southeast region of the United States.

The most common method of fumigation is to "tent" the structure (the structure is vacated); then the entire structure, or portions of the structure, are covered with gas proof sheets (4-6 mm polyethylene or coated nylon sheets). Some structures can be "sealed" using tape or paper and covering vents with polyethylene. The tenting process with a trained crew can take 3 to 5 hours, depending on the structure. Large structures may take several days to either "tent" or "tape and seal." After tenting, the gas is then injected into the structure from pressurized cylinders. The common amount is 0.5-1.0 pounds/1000 cubic feet for drywood termites. Dosages of fumigant will vary depending on insect species, temperatures, size of structure, etc. For example, the wood destroying beetles may take several times the 1-pound dosage recommended for drywood termites. This procedure is quick and can be handled efficiently by trained crews. The average time for effective fumigation for these insects is 24 hours. However, shorter times can be used when factors dictate this procedure.

When the structure is "opened," the ventilation of the building is easily done using fans. Monitoring devices are used to clean the structure prior to reoccupancy.

As mentioned, fumigants have been used for other pests. This method allows for quick removal, elimination, of a pest problem. These fumigations are generally quick, less than 12 hours, and inexpensive when considered an ongoing pesticide application program.

Amounts and Costs

The most difficult aspect of presenting these figures is that they are generally not available. States do not keep records for specific usages, only totals. The cost of a fumigation will vary from region to region because the frequency of fumigation is different as well as the competition between companies.

An example is to compare the southeast to the northeast. If you consider the average size structure in the southeast of 2000 square feet, approximately 20,000 cubic feet; this could be fumigated for an average of $500 to $600, while in the northeast it may be as much as $1,500 to $2,000 for the same size structure.

Also, one must consider the target pest. The southeast has a great number of drywood termite infestations. The fumigants used are very effective at low dosages for these insects. Beetles require five to ten times as much, depending on the fumigant. Beetles are more of a common problem in the northeast.

It is estimated by the U.S. Department of Agriculture that in the southeast over $12.9 million in damage occurs due to beetle infestations (4). Loss data for drywood termites and Formosan termites are not available. A cost estimate for the Formosan termite, made by the National Pest Control Association, would be over $10 million, several million dollars in Hawaii alone (2).

The NPCA was not able to obtain exact figures on quantity of fumigants used specifically for structural fumigation. We refer to the 1983 National Urban Pesticide Applicator Survey (NUPAS) for figures generated for that year. Since then, increased use of Vikane™ can be accounted for by the industry (1).

The quantities of the two fumigants used vary from region to region. Over 2 million pounds of sulfuryl fluoride ($7.89 per pound) and approximately 1.5 million pounds of methyl bromide ($1.58 per pound) are used for structural fumigations (Table 1). Total fumigant cost is approximately $18.4 million. The methyl bromide figure is a rough estimate because of its widespread effective use in commodity fumigation. Sulfuryl fluoride is used almost entirely for structural fumigation.

Using these figures we can estimate the approximate amount of cubic feet treated annually for these wood destroying insects. Taking into account the variations in the amounts of fumigant used, the average for a given 1000 cubic feet would be 8 ounces (for either fumigant). This would result in a figure of 7 billion cubic feet fumigated each year.

Table 1. Use and Cost of Fumigants and Alternatives.

Fumigants: Sulfuryl fluoride
Methyl bromide

Quantity used/year: 2 million pounds sulfuryl fluoride
1.5 million pounds methyl bromide

Average amount used/1000 ft^3: 8 oz

Number of structures fumigated: 35,000

Total ft^3 fumigated/year: 7 billion (4 billion - sulfuryl fluoride)
(3 billion - methyl bromide)

Average cost of fumigating each structure (materials and labor): $700

Total annual fumigation cost: $24.5 million

Average cost of alternative treatment: $2,500

Total cost of alternative treatment: $87.5 million

Structures Treated

All sizes and types of structures have been treated; large high-rise buildings in Hawaii and Florida have been treated for Formosan and drywood termites.

Most structures treated are residences which vary in architecture and size. In recent years, the marketing of log homes have created another problem. Beetle infestations in these homes are common and can be eliminated by fumigation. The net result based on figures cited above would be an estimate of 35,000 structures fumigated each year (Table 1).

Alternatives

Alternatives to fumigation can be costly. Repair or replacement of timbers is one method, but one has to be sure the entire infestation has been detected and removed. This is virtually impossible in a structure since it would require dismantling walls, ceilings, etc. The replaced wood should be pressure-treated to limit the possibility of reinfestation.

Localized treatments with liquid pesticides, either applied as a spray or injected into the wood, will kill emerging adult beetles from infested wood. This method will also kill some larvae that venture close to the surface of the wood prior to pupation. There are three chemicals presently registered for this use: pentachlorophenol, lindane, and chlorpyrifos. These can be sprayed or

painted on the wood. Again, all the infested wood must be treated to assure kill of emerging beetles. Estimates on the costs of these treatments would depend on area size to be treated. Average figures would be $200 to $300, this is for treated exposed wood. Opening walls, ceilings, etc., would be an added cost.

There are also pesticide dusts and aerosol formulations of liquid insecticides registered for spot treatment of drywood termite galleries. This requires location and application into the termite colonies.

All of these methods are effective if all infestations are found and treated. Localized treatment for beetles does not stop damage the larvae can continue to cause prior to pupation and emergence.

Since some beetle infestations may die out, another method is to allow the infestation to do this. This method is usually not acceptable to occupants of the infested structure. The federal loan agencies (FHA, FmHA or VA) do not recognize localized treatment for beetles or drywood termites for loan guarantees.

Costs and Benefits of Structural Fumigation

Fumigation is an economical and effective method of controling structural insect infestations. The fumigants used penetrate quickly and can be aired from the structure in a matter of hours after "opening" the structure.

Costs based on average figures for chemical cost ($300 to $500/structure) and industry figures for performing fumigation ($300/structure) would indicate a total of approximately $24.5 million for fumigating 35,000 structures (Table 1). If fumigants were not available, and repairs, replacement, and localized treatment methods were used as alternatives, an estimated average figure would be approximately $2,500/structure. This would result in a figure of $87.5 million for alternative treatment, a difference of $63 million. There is also a potential for major structural damage in some instances, which would result in additional repair costs between $10,000 to $15,000/structure for repair work.

It is also important to note that loss of fumigants could sometimes result in loss of loan approval by FHA, FmHA and VA, when houses are infested.

The industry and the Environmental Protection Agency have both undertaken a program of education and label improvement to make the use of fumigant materials safe and effective.

References

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